Humanities

Transformative conservation: The biopolitical interventions, reconstituted natures, and future cosmologies of emerging conservation proposals

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #2017-0102

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Abstract

Since its formal inception as a discipline in the 1980s, conservation biology has been the terrain of discussions, debates and often conflicting attempts at defining what its object, scope, and allies should be. This dissertation investigates contemporary shifts in this field, and in particular a set of recent transformative conservation proposals, with a view to tracing changing definitions of nature, wildlife and survival, and analysing the transformations that conservation biology politics are undergoing in an era of "postnormal" science.

This dissertation explores three case studies: the assisted migration of endangered plants, the conservation of crop wild relatives in view of breeding them with food crops, and the assisted evolution through selective breeding of corals. Defined as examples of an emerging current of "transformative conservation", these marginal and sometimes controversial proposals are less concerned with essences than with processes, indicative of a new conservation epistemology predicated on relational ontologies and immanent ecological assemblages, and willing to intervene directly in various dimensions of nonhuman life by enrolling the unpredictability of different geographical, genealogical and temporal processes.

Making use of sustained documentary research, this dissertation explores the biopolitical categories structuring each of these projects: circulatory governmentality in assisted migration, the manipulation of the relational space between categories of species in crop wild relative conservation, and the instrumentalisation of genetic and metabolic processes in coral assisted evolution. However, it argues that transformative conservation practices also contain the possibility of oppositional politics, and reveals in each instance the presence of discursive and material negotiations with changing physical, temporal and social landscapes that exceed the project of mastery and control over nonhumans. Ultimately, it shows that transformative conservation is cosmologically and not only biopolitically productive, even when the practices and discourse of the practitioners involved in these projects remain indebted to impoverished epistemological and ontological nomenclatures.

Keywords: environmental humanities, conservation biology, biopolitics, extinction, transformative conservation, assisted migration, crop wild relatives, assisted evolution

Résumé

Depuis son institution en tant que discipline formellement reconnue dans les années 1980, la biologie de la conservation a été le terrain de discussions, de débats et de tentatives parfois contradictoires de définir ce que devraient être ses objets, sa portée et ses alliés. Cette thèse étudie les mutations contemporaines de la discipline, et en particulier un ensemble de projets de conservation transformatrice récemment proposés ou implémentés, avec pour but d'analyser comment ces projets redéfinissent ce qu'est la nature, le sauvage, et la survie en période d'extinctions accélérées, ainsi que de tracer les mutations de la politique conservationniste dans un contexte de science « postnormale ».

Cette thèse est structurée autour de trois cas d'études : la migration assistée de plantes menacées, l'utilisation d'espèces sauvages cousines dans des programmes agricoles d'hybridation, et enfin l'évolution assistée de coraux. Ces propositions marginales et parfois controversées, définies ici comme exemples d'une « conservation transformatrice » émergente, sont moins préoccupées par l'essence d'espèces sauvages que par les processus qui les structurent. Elles sont indicatives d'une nouvelle épistémologie conservationniste, et impliquent d'intervenir directement dans différents aspects de vies nonhumaines en manipulant divers processus géographiques, généalogiques et temporels.

Sur la base de recherches documentaires exhaustives, cette thèse explore les catégories biopolitiques qui structurent chacun de ces projets : une gouvernementalité circulatoire dans le cas de la migration assistée, la manipulation de l'espace relationnel entre deux catégories d'espèces dans la conservation d'espèces sauvages cousines, et l'instrumentalisation de processus génétiques et métaboliques dans le cas de l'évolution assistée. Mais les pratiques de conservation transformatrice peuvent également être étudiées comme le terrain d'une politique oppositionnelle, et cette thèse révèle la présence, dans chaque cas d'étude, de négociations discursives et matérielles avec de nouvelles conditions physiques, temporelles et sociales, négociations qui excèdent un simple projet de maîtrise et de contrôle sur le nonhumain. Cette thèse démontre que la conservation transformatrice est productive non seulement d'un point de vue biopolitique, mais également dans sa dimension cosmologique, quand bien même les pratiques et discours conservationnistes restent soumis à des nomenclatures épistémologiques et ontologiques appauvries.

Mots clés : humanités environnementales, biologie de la conservation, biopolitique, extinction, conservation transformatrice, migration assistée, crop wild relatives, évolution assistée

Résumé substantiel

En 2014, une conférence organisée par la Western Society of Naturalists accueillait deux scientifiques depuis longtemps opposés. Michael Soulé, l'un des fondateurs de la biologie de la conservation, et Peter Kareiva, porte-parole du courant de la « nouvelle conservation », devaient présenter durant la matinée du premier jour. Le public s'attendait à ce qu'ils mentionnent le débat concernant le futur de la discipline dans lequel ils étaient engagés depuis des années, débat qualifié par le journaliste rapportant cette anecdote de « bataille pour l'âme de la science de la conservation ».[1] En fin de compte, leurs présentations respectives ce jour-là ont contourné les aspects les plus clivants de ce débat; mais l'attente d'une confrontation majeure entre ces deux figures est elle-même révélatrice des transformations cruciales actuellement en cours dans ce domaine.

Une des nombreuses questions qui divisent écologistes traditionnels et nouveaux concerne le degré de résilience de certaines espèces et certains écosystèmes. Doit-on considérer que cette résilience peut leur permettre de s'adapter à de nouvelles conditions environnementales dangereuses et destructrices – et dans ce cas, jusqu'où la biologie de la conservation devrait non seulement accepter mais collaborer avec des conditions environnementales changeantes et nouvelles ? Les « nouveaux » conservationnistes, ainsi qu'un certain nombre de vulgarisateurs scientifiques, ont proposé une lecture optimiste des perturbations de l'Anthropocène et de la nouveauté génétique et écosystémique qu'elles apportent. Toutes sortes d'hybridations, de spéciations, et la formation de nouveaux écosystèmes ont été présentées comme signes de la productivité potentielle de catastrophes environnementales, qui pourraient générer de nouvelles façon de vivre ensemble – du moins pour les quelques espèces suffisamment entrepreneuriales pour tirer profit de ces nouvelles niches.[2] Ce débat a convergé avec l'avènement d'avancées technologiques en conservation, avancées qui ont

[1] Cf. Keith Kloor, "The Battle for the Soul of Conservation Science," *Issues in Science and Technology* 31, no. 2 (2015): 74–79.

[2] Cf. par exemple Chris D. Thomas, "Rapid Acceleration of Plant Speciation during the Anthropocene," *Trends in Ecology & Evolution* 30, no. 8 (August 2015): 448–55; Richard J. Hobbs, Eric S. Higgs, and Carol M. Hall, eds., *Novel Ecosystems: Intervening in the New Ecological World Order* (Chichester: Wiley-Blackwell, 2013); Emma Marris, *Rambunctious Garden: Saving Nature in a Post-Wild World* (New York: Bloomsbury, 2011); Fred Pearce, *The New Wild: Why Invasive Species Will Be Nature's Salvation* (London: Icon Books, 2015).

considérablement étendu les possibilités d'intervenir dans les processus biologiques végétaux et animaux.

Cette thèse a évolué à partir d'un intérêt initial pour la conservation ex situ d'espèces sauvages menacées (dans des zoos et jardins botaniques, sous forme de populations captives ou de banques de graines ou de gamètes), et de la volonté d'analyser les contradictions inhérentes au projet de préserver plantes et animaux dans des collections statiques au moment même où la composition écologique de la planète est marquée par une instabilité croissante. Mais en examinant les pratiques et technologies de la conservation ex situ, il m'est rapidement apparu que ces institutions sont tout aussi affectées par les transformations actuelles du monde conservationniste que les initiatives in situ, et qu'elles sont en cours de réorientation vers des projets que je désigne collectivement comme conservation transformatrice. Zoos, jardins botaniques, banques de grains et banques de gènes ne sont pas uniquement des espaces dans lesquels des vies sont suspendues ou réduites à de l'information génétique ; ces institutions sont toujours impliquées dans une mise en circulation intensive des espèces qu'elles accueillent, et les font participer à de nombreux projets reproductifs et expérimentaux. Il semble donc moins immédiatement important d'étudier les contradictions entre conservation ex situ et transformations environnementales catastrophiques que d'analyser la politique des transactions riches et variées qui ont toujours lieu ex situ.

Dans cette thèse, je définis la conservation transformatrice comme un ensemble de pratiques traitant les espèces ou individus qu'elles souhaitent protéger comme des sujets plastiques et pourvus d'une certaine *agency* individuelle et inter-individuelle. Ces projets sont liés à un ensemble de techniques de conservation incluant le ré-ensauvagement, la dé-extinction, le clonage, la gestion de nouveaux écosystèmes ou d'écologies urbaines – en bref, des pratiques qui pourraient être caractérisées comme « post-normales » ou de « conservation après la nature », moins essentialistes que processuelles, et dont l'émergence est indicative d'une nouvelle épistémologie de la conservation basée sur une ontologie relationnelle et sur la reconnaissance d'assemblages immanents.[3] Les propositions marginales et parfois controversées examinées ici – la migration assistée, la conservation d'espèces sauvages cousines, et

[3] Cf. par exemple Katja Grötzner Neves, *Postnormal Conservation. Botanic Gardens and the Reordering of Biodiversity Governance* (Albany: State University of New York Press, 2019) et Jamie Lorimer, *Wildlife in the Anthropocene. Conservation after Nature* (Minneapolis: University of Minnesota Press, 2015).

l'évolution assistée – cherchent toutes à transformer où à faire usage de ce qu'elles disent sauvegarder, et elles manipulent un ensemble de processus géographiques, généalogiques et temporels afin de sécuriser les futurs potentiels de ces espèces. Je propose de lire ces pratiques à la fois comme formes de pouvoir permettant des interventions biopolitiques et comme formes de négociations quasi- ou proto-cosmologiques. Ce double cadre évite d'uniformiser ces pratiques et de les traiter seulement comme des exemples variés mais essentiellement semblables d'une modernité hypertrophiée, de l'extension d'une domination humaine sur une nature nonhumaine, ou de rêves d'une maîtrise absolue sur la vie elle-même. Une analyse de pratiques de conservation transformatrices comme lieux de création et de simulation plutôt que comme expressions d'une rationalité gouvernementale unifiée permet de rendre visibles les négociations et contestations dans lesquelles ces scientifiques sont impliqués.

Le but de cette thèse est donc de proposer une analyse critique d'un tournant plus vaste de la discipline vers des conceptions « postnormales », relationnelles, ou néolibérales de la nature ; de tracer la résurgence de pratiques passées dans ces propositions contemporaines afin d'étudier la façon dont elles mobilisent certaines compétences et les préoccupations botaniques, agricoles et horticoles ; et, enfin, de dégager le potentiel spéculatif de chaque projet afin d'examiner la politique oppositionnelle qu'ils pourraient rendre possible quand ils s'engagent dans la création expérimentale de mondes et de futurs.

Chapitre 1. « Une discipline de crise » : les topologies glissantes de la conservation

Ce chapitre fournit un aperçu du terrain sur lequel se situe mon enquête et des travaux auxquels elle répond et contribue. Dans un premier temps, je résume le contexte historique dans lequel la biologie de la conservation a émergé en tant que discipline, avec comme point d'entrée le moment où celle-ci s'est confrontée aux théories postmodernes concernant la construction sociale de la nature. A partir de cette introduction, je remonte à la création de la biologie de la conservation comme « science de crise », tout en soulignant la nature expérimentale et pragmatique des pratiques dont elle est composée. S'ensuit un bref historique de la conservation ex situ, qui forme le terrain privilégié de cette enquête.

Ce chapitre s'ouvre sur un rappel de la publication, en 1995, d'un volume intitulé *Reinventing Nature? Responses to Postmodern Deconstruction*. Édité par Michael Soulé et Gary Lease, ce volume se veut une défense du concept de nature contre les débordements perçus du postmodernisme Ce dernier était à cette époque assimilé par de nombreux biologistes à un blanc-seing autorisant l'intervention humaine dans le milieu naturel sous prétexte que celui-ci est de tout façon socialement construit et donc artificiel, assimilation nourrissant les craintes de voir la construction sociale de la nature justifier son exploitation.

La mention de ce volume sert à rappeler que prendre le débat constructionniste comme point d'entrée dans la conservation transformatrice ne peut conduire qu'à un redoublement stérile du débat déjà mené dans les années 1990. Il ne s'agit pas ici d'accuser écologistes et conservationnistes de myopie conceptuelle, et il faut pour cela remonter à une époque précédant la publication de ce volume. Les écologistes ayant fondé la discipline, bien qu'engagés dans des formes d'essentialisation stratégique de leurs objets d'étude dans les années 1990, étaient à l'origine moins réticents quant à l'interventionnisme de leurs pratiques, et ont parfois explicitement nommé les transactions compliquant la frontière entre le donné et le construit. Ainsi, l'article fondateur publié en 1985 par Michael Soulé, « What is Conservation Biology ? », déclare qu'il « est souvent nécessaire de tolérer l'incertitude » en conservation, et que

> Presque tous les programmes de conservation devront être épaulés artificiellement […]. Le braconnage, la fragmentation d'habitats, et l'afflux d'animaux sauvages et de plantes exotiques exigent des pratiques extraordinaires telles que l'abattage, l'éradication, l'immunisation d'animaux sauvages, la protection de certains habitats, et les transferts artificiels.[4]

Les bases de la biologie de la conservation, une « structure synthétique, éclectique, multidisciplinaire », furent posées lors d'un banquet organisé en 1978 au San Diego Wild Animal Park,[5] un évènement réunissant « un groupe hétéroclite de chercheurs, de gardiens de zoo et de conservationnistes. »[6] Cette réunion fut suivie entre autres par la

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[4] "[…] virtually all conservation programs will need to be buttressed artificially […] poaching, habitat fragmentation, and the influx of feral animals and exotic plants require extraordinary practices such as culling, eradication, wildlife immunization, habitat protection, and artificial transfers". Michael E. Soulé, "What Is Conservation Biology?", *BioScience* 35, no. 11 (1985): 9, 729.

[5] Fred Van Dyke, *Conservation Biology: Foundations, Concepts, Applications* (Dordrecht: Springer Netherlands, 2008), 3.

[6] Ann Gibbons, "Conservation Biology in the Fast Lane," *Science* 255, no. 5040 (1992): 20–22, 20.

publication d'un volume fondateur, *Conservation Biology : An Evolutionary-Ecological Perspective*, et mena en fin de compte à l'etablissement formel d'une nouvelle discipline lors de la création de la Society for Conservation Biology en 1985.

C'est à Soulé que revient l'honneur d'avoir formulé la définition séminale de la discipline dans un article structuré autour de la notion de *biodiversité* comme objet principal de la biologie de la conservation. Selon lui, la biologie de la conservation se distingue d'autres disciplines biologiques par son contexte de crise. C'est ce contexte qui conditionne la nécessité d'emprunter les méthodes et connaissances d'une vaste gamme de disciplines, et qui mène à estomper les frontières entre les sciences pures et appliquées. De plus, la biologie de la conservation est holistique et vise la viabilité sur le long terme de ses projets. Enfin, Soulé explique que la discipline ne vise pas tant le bien-être animal ou la préservation de certains individus, mais bien plutôt la santé et la viabilité de populations entières.[7]

Malgré cette volonté de présenter une définition unifiée de la discipline lors de sa création, la biologie de la conservation n'est pas un champ monolithique et homogène, et il est à la fois réducteur et précipité de vouloir analyser une topologie composée de projets multiples et souvent contradictoires à travers un seul prisme.[8] Ceci est particulièrement évident lorsqu'on se penche sur les débats concernant les lieux dans lesquels les espèces sauvages devraient être conservées. La question des relations entre territoires, marges, frontières et routes migratoires a formé l'un des objets par excellence de la conservation ces cinquante dernières années. Les géographies (et la géopolitique) de la conservation sont perméables, contestées, et situées à l'intersection d'actions humaines et nonhumaines, comme l'ont par exemple montré les nombreux débats, dans les années 1980 et 1990, autour des mérites respectifs de grandes réserves naturelles isolées ou de sites plus restreints mais connectés par des corridors verts. Pendant que la communauté conservationniste était engagée dans ces tentatives de contestation, de retraçage et de connexion des frontières de réserves naturelles, de nombreux scientifiques ont également tenté de réévaluer les rôles passés et futurs d'institutions dans lesquelles des espèces menacées étaient maintenues en captivité. Ces réflexions ont finalement mené à une intégration progressive d'institutions problématiques, telles que les jardins zoologiques,

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7 Soulé, "What Is Conservation Biology?"

8 Donna Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016), 41.

et botaniques, dans des programmes de conservation plus vastes – et à l'importance croissante de la conservation ex situ en général.

La Convention on Biological Diversity de 1992 définit la conservation ex situ (par opposition à la conservation in situ, par exemple dans de réserves naturelles) comme la « conservation d'éléments de la diversité biologique en dehors de leurs habitats naturels ».[9] La International Union for Conservation of Nature indique que la liste des habitats artificiels dans lesquels ces espèces peuvent être conservées inclut « les collections de plantes ou d'animaux entiers, les parc zoologiques et jardins botaniques, des établissements de recherche sur la faune sauvage, et les banques de matériel génétique de taxons sauvages et domestiqués. »[10] Autour de la fin des années 1980 et durant les années 1990, la conservation ex situ a été dominée par le « paradigme de l'arche »,[11] un terme inspiré par un article publié en 1986 par Soulé, Gilpin, Conway et Foose. La proposition formulée dans cet article est de transformer les jardins zoologiques, jusqu'ici voués au spectacle et au divertissement, en sites de stockages de diversité génétique, afin de survivre à un « hiver démographique de 500 à 1000 ans qui éliminerait la plupart des habitats tropicaux disponibles pour les espèces sauvages », à la suite duquel les auteurs estiment que l'extension d'habitats potentiels augmentera à nouveau.[12]

Ce paradigme de l'arche est désormais obsolète, et la conservation ex situ s'est réorientée vers des approches plus intégrées et une collaboration plus soutenue avec des initiatives in situ. Les collections ex situ sont maintenant considérées comme des filets de sécurité utiles qui complètent la conservation d'espèces sauvages dans leur milieu naturel plutôt que comme des arches sécurisées permettant de différer l'extinction d'une espèce dans la nature. Mais cette collaboration est compliquée par les difficultés inhérentes à l'élevage de populations viables en captivité. Les banques de graines associées à des jardins botaniques rencontrent en général moins de difficultés quand

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[9] "The conservation of components of biological diversity outside their natural habitats." Convention on Biological Diversity, art. 2.

[10] "whole plant or animal collections, zoological parks and botanic gardens, wildlife research facilities, and germplasm collections of wild and domesticated taxa". IUCN, "IUCN Technical Guidelines on the Management of Ex Situ Populations for Conservation" (2002).

[11] Andrew E. Bowkett, "Recent Captive-Breeding Proposals and the Return of the Ark Concept to Global Species Conservation," *Conservation Biology* 23, no. 3 (June 2009): 773–76, 774.

[12] "[…] a demographic winter lasting 500–1,000 years and eliminating most habitat for wildlife in the tropics," Michael Soulé et al., "The Millenium Ark: How Long a Voyage, How Many Staterooms, How Many Passengers?," *Zoo Biology* 5, no. 2 (1986): 101–13, 101.

il s'agit de reproduire des plantes à des fins de réintroduction et de stocker de grandes quantités de graines, mais les zoos ont vu leur activité de reproduction en captivité décliner quelque peu au cours du XXIe siècle, et la question de savoir si leur activité est utile en termes de conservation est régulièrement posée.[13]

Quoi qu'il en soit, ces institutions se sont progressivement réinsérées dans une topologie dynamique composée de différents espaces de conservation, une écologie de pratiques dans laquelle elles cherchent à collaborer avec des modes de survie et de création de mondes plus ancrés dans leur environnement. Cette transformation a poussé la communauté conservationniste à repenser ces institutions comme lieux connectés de façon dynamique à leur environnement, qu'elles peuvent influencer et dans lesquels elles peuvent intervenir – y compris de façon dangereuse, comme le montre le débat houleux sur l'introduction d'espèces invasives via un certain nombre de jardins botaniques. Ces institutions apparaissent maintenant comme hétérotopies, des espaces *autres* par excellence dans lesquels l'attention est redirigée et les sujets transformés, des dispositifs semiotiques et technologiques qui permettent de manipuler l'espace, le temps et les généalogies.[14] C'est en prêtant attention à ce qui se passe à la charnière de la conservation ex et in situ et à la façon dont les transactions entre les deux sont en cours de reconfiguration qu'il sera possible de voir comment ces institutions deviennent des acteurs politiques, des centres de calcul et des sites où émergent des formations biosociales.[15] C'est ce que propose Kay Lewis-Jones quand elle suggère que la Millennium Seed Bank, la plus vaste banque de graines sauvages au monde, « pourrait favoriser un espace liminal et créer un sentiment de communitas liant humains et plantes ». Le travail ethnographique qu'elle entreprend dans cette institution révèle clairement que la Millennium Seed Bank ne fonctionne pas uniquement comme un vaste réfrigérateur pour des graines maintenues en suspension.[16] Elle permet au contraire des formes de reconfiguration matérielle et de collaboration entre agents, et ce dans un espace dans lequel les vies sociales de ces diverses espèces peuvent s'entrecroiser et s'influencer

[13] Voir par exemple le problème du biais taxonomique en faveur d'espèces charismatique, discuté dans J. E. Fa et al., "Zoos Have yet to Unveil Their Full Conservation Potential," *Animal Conservation* 17, no. 2 (2014): 97–100. Voir aussi Jenny Gray, *Zoo Ethics: The Challenges of Compassionate Conservation* (Ithaca: Cornell University Press, 2017).

[14] Cf. Michel Foucault, "Of Other Spaces," trans. Jay Miskowiec, *Diacritics* 16, no. 1 (1986): 22–27.

[15] Cf. Latour, *Science in Action*.

[16] Kay E. Lewis-Jones, 'Holding the Wild in the Seed: Place, Escape and Liminality at the Millennium Seed Bank Partnership', *Anthropology Today* 35, no. 2 (April 2019): 3–7, 6.

mutuellement. Comme le suggèrent Esther Breithoff et Rodney Harrison dans leur étude critique de la Frozen Ark, les collections conservées ex situ sont elles-mêmes un « terrain ». La nature dynamique des procès qui animent ce terrain signifie que la diversité assemblée dans ce type de banque est toujours une *biodiversité expérimentale*.

C'est ainsi que j'en viens à étudier la conservation ex situ comme le terrain dynamique de transactions complexes. En traitant ce domaine comme un terrain influencé par le commerce, la délocalisation, l'exploitation et la circulation d'espèces nonhumaines, et comme un lieu dans lequel la suspension et la gestion de processus vitaux n'est jamais tout à fait garantie ou achevée, je me suis rendue attentive aux nombreux projets dans lesquels circulent ces collections captives. Lors d'un entretien avec un employé du Arnold Arboretum, à Harvard, cette institution m'a été décrite explicitement comme un lieu expérimental, une « boîte de Petri » dans laquelle il est possible d'explorer ce qui se passe quand un musée, une collection vivante, un dispositif de recherche et des projets de conservation se rencontrent. C'est cette description qui m'a en première mise sur la piste des projets de migration assistée dans lesquels l'arboretum était impliqué. Plutôt que de chercher à conserver uniquement une flore locale, les chercheurs et jardiniers de l'arboretum tentent de faire en sorte à ce que cette institution reste « à la pointe de l'introduction de plantes (en particulier dans un monde de changements environnementaux rapides) », un projet qui implique de « chercher, acquérir et tester des espèces inexplorées qui pourrait pousser dans l'enceinte » - en particulier des taxons vivaces existant aux franges climatiques du Massachussetts, et qui pourraient prospérer dans cette région dans des conditions climatiques dégradées.[17] C'est en suivant ce fil conducteur et en repérant comment ce type de collection et de lieu sont mobilisés dans différents projets que j'en suis arrivée à ce que j'appelle la conservation transformatrice. La migration assistée, la conservation d'espèces cousines sauvages et l'évolution assistée émergent toutes des espaces de plus en plus laboratisés peuplant la conservation ex situ, et du flou politique et éthique créé par un tournant néolibéral récent en biologie de la conservation.

Le cadre théorique des chapitres suivants doit beaucoup à l'analyse foucaltienne des formations de pouvoir/savoir et processus d'assujettissement, et en particulier aux travaux qui ont étendu les notions de biopolitique, de biopouvoir et de gouvernance au-

[17] William E Friedman et al., "Developing an Exemplary Collection: A Vision for the Next Century at the Arnold Arboretum of Harvard University" 73, no. 3 (February 2016): 4–18, 7.

delà de l'humain.[18] Certaines études critiques de la biologie de la conservation ont ouvert ce champ encore plus largement en appliquant ces concepts à la façon dont les projets de conservation gèrent des populations plutôt que des individus, et en analysant la logique de l'anormalité inhérente au concept de biodiversité et de sa préservation, la politique reproductive imposée aux espèces menacées, et les nombreuses manières de sécuriser la vie contre le danger d'extinction.[19] Ces concepts seront combinés avec le travail de penseurs tels qu'Isabelle Stengers, Bruno Latour et Donna Haraway, et en particulier leurs analyses des effets ontologiques de certaines pratiques technologiques et scientifiques.

Appliquer une grille de lecture biopolitique à la biologie de conservations permet d'en pluraliser les composantes et les pratiques plutôt que d'essayer de les ordonner dans un système unifié et universel. Le travail de Timothy Hodgetts est un bon exemple de cette approche : en analysant en détail deux cas d'étude (la conservation d'écureuils roux et de martres des pins au Royaume-Uni), il montre que ces deux projets relèvent de modes biopolitiques différents – l'un est concentré sur la gestion disciplinaire de ses sujets, l'autre sur des techniques de sécurité qui impliquent la création de milieux vivables. Ces deux projets ne constituent pas leurs sujets de la même façon, et le statut politique des animaux concernés dépend de quelle espèce est gérée dans quel contexte. Il est important de procéder à de telles distinctions fines quand il s'agit de pratiques transformatrices jouxtant le domaine des interventions technoscientifiques de l'ingénierie. Il serait trop facile de les lire comme des déclinaisons du même projet de contrôle et de maîtrise, alors qu'elles sont en réalité beaucoup plus atomisées, contingentes et incertaines.

En plus de ce cadre biopolitique, cette thèse fera appel à un pan de la littérature anthropologique concernant les relations entre humains et nonhumains, comme par

[18] Cf. *Donna Haraway, When Species Meet* (Minneapolis: University of Minnesota Press, 2007); Sara Rinfret, "Controlling Animals: Power, Foucault, and Species Management," *Society & Natural Resources* 22, no. 6 (4 June 2009): 571–78; Jeffrey T. Nealon, *Plant Theory: Biopower and Vegetable Life* (Stanford: Stanford University Press, 2015). Cf. également Chloë Taylor, "Foucault and Critical Animal Studies: Genealogies of Agricultural Power," *Philosophy Compass* 8, no. 6 (1 June 2013): 539–51.

[19] Cf. par exemple Lorimer*, Wildlife in the Anthropocene*; Christine Biermann and Robert M. Anderson, "Conservation, Biopolitics, and the Governance of Life and Death," *Geography Compass* 11, no. 10 (October 2017): e12329; Christine Biermann and Becky Mansfield, "Biodiversity, Purity, and Death: Conservation Biology as Biopolitics," *Environment and Planning D: Society and Space* 32, no. 2 (April 2014): 257–73; Krithika Srinivasan, "Caring for the Collective: Biopower and Agential Subjectification in Wildlife Conservation," *Environment and Planning D: Society and Space* 32, no. 3 (1 January 2014): 501–17; et Steve Hinchliffe and Kim J. Ward, "Geographies of Folded Life: How Immunity Reframes Biosecurity," *Geoforum* 53 (1 May 2014): 136–44.

exemple les travaux de Frédéric Keck sur les pandémies de grippes aviaires, les analyses d'Anna Tsing concernant les écologies de plantations, ou les études comparées de cosmologies indigènes et conservationnistes d'Istvan Praet.[20] Ce cadre conceptuel éclectique reflète le double mouvement qui guide mon analyse de chaque cas d'étude : je traite ces exemples à la fois comme des formations de pouvoir/savoir qui assujettissent certaines espèces menacées de nouvelles façon et comme pratiques pouvant être étudiées dans leurs dimensions anthropologiques ou cosmologiques, ce qui les resitue dans un contexte d'interactions anciennes et continues entre humains et nonhumains. Ces deux approches sont complémentaires et permettent d'analyser ces projets de conservation en tant qu'exemples de ce que Stengers appelle « cosmopolitique », autrement dit le processus constructif de composition de mondes communs avec un ensemble hétérogène de créatures autres et de pratiques radicalement divergentes. L'idée que la biologie de la conservation esquisse des gestes cosmopolitiques peut être comprise au moins de deux façons : premièrement, comme une réinscription d'interventions humaines dans un contexte historique qui permet de les lier à d'autres formes de diplomaties interespèces ; et deuxièmement comme l'idée que la conservation est elle-même déjà engagée dans la création de ce qui pourrait être désigné comme *cosmologies*, à savoir la création de façons d'ordonner l'espace et le temps, la vie et la mort, afin des rendre habitables ou compréhensibles.

Cette thèse est basée sur des recherches documentaires détaillées concernant les origines et les transformations de la biologie de la conservation, ainsi que les trois cas d'étude que je propose d'étudier ici. Cette composante empirique inclut un corpus varié, principalement composé de littérature scientifique (en particulier d'articles parus dans différents journaux académiques d'écologie et de de conservation, de volumes édités et de manuels de conservation) mais également de données historiques concernant la discipline, d'enregistrements de présentations et d'entretiens donnés par les scientifiques impliqués dans les projets étudiés, de documentaires, d'ouvrages de vulgarisation scientifique, et parfois d'entretiens cités dans d'autres ouvrages sur

[20] Cf. Frédéric Keck, *Avian Reservoirs: Virus Hunters and Birdwatchers in Chinese Sentinel Posts* (Durham: Duke University Press, 2020); Anna Lowenhaupt Tsing, 'A Threat to Holocene Resurgence Is a Threat to Livability', in *The Anthropology of Sustainability Beyond Development and Progress*, ed. Mark Brightman and Jerome Lewis (New York: Palgrave Macmillan, 2017); et Istvan Praet, "Animal Conceptions in Animism and Conservation: Their Rootedness in Distinct Longue Durée Notions of Life and Death," in *Routledge Handbook of Human-Animal Studies*, ed. Garry Marvin and Susan McHugh (London, New York: Routledge, 2014).

lesquels je m'appuie. J'ai également procédé, entre 2016 et 2020, à une série d'entretiens informels et non-structurés avec certains scientifiques et autres employés travaillant dans les institutions dont traite cette thèse. Ces entretiens n'ont pas l'ambition d'atteindre la cohérence et l'étendue d'un travail de terrain anthropologique, et servent principalement de complément au reste de la recherche empirique qui sous-tend cette thèse et comme indicateurs de certaines tendances dans ce domaine. C'est pourquoi ils apparaissent sous forme de courtes vignettes distribuées à travers le texte de cette thèse, plutôt que comme un corpus de données ethnographiques complet. Ils ont souvent servi à faciliter ma progression à travers une littérature scientifique abondante et dense, un paysage dans lequel mes interlocuteurs ont agi comme guides facilitant mon adaptation à un terrain peu familier. Les plus anciennes de ces discussions, bien qu'elles ne soient pas citées dans ce chapitre, ont contribué à former ma compréhension de la conservation ex situ comme pratique dynamique et transformatrice. Les entretiens plus tardifs ont souvent été conduits une fois la phase de recherche empirique terminée, et m'ont permis de poser des questions supplémentaires et d'évaluer la robustesse des arguments développés à partir de cette recherche.

Chapitre 2. « Peut-être en les aidant à se déplacer » : migration assistée et changement climatique

Le premier cas d'étude de cette thèse porte sur la migration assistée, une proposition de conservation récente et controversée. La migration assistée a été définie comme

> La préservation de la diversité biologique à travers le transfert de représentants d'une espèce ou d'une population affectée par des changements climatiques vers une zone située en dehors de son habitat indigène, et vers laquelle il est estimé que [cette espèce ou cette population] se déplacerait en conséquence de changements climatique si elle en avait le temps et ne rencontrait pas d'obstacles anthropogéniques.[21]

[21] "Safeguarding biological diversity through the translocation of representatives of a species or population harmed by climate change to an area outside the indigenous range of that unit where it would be predicted to move as climate changes, were it not for anthropogenic dispersal barriers or lack of time", Maria H. Hällfors et al., 'Coming to Terms with the Concept of Moving Species Threatened by Climate Change – A Systematic Review of the Terminology and Definitions', *PLOS ONE* 9, no. 7 (23 July 2014): e102979, 10.

Cette idée est relativement nouvelle en conservation, et représente un projet très différent de celui de créer des corridors verts afin de faciliter la migration d'espèces entre des zones fragmentées. Elle apparut pour la première fois dans un article publié en 1985 par Joan Darling et Robert Peters, mais ne fut reprise plus largement que deux décennies plus tard. La création du terme lui-même est souvent attribué à Brian Keel,[22] et le concept a été repris et disséminé en particulier par un groupe de volontaires très controversé, les Torreya Guardians, qui cherchent à replanter un conifère menacé au-delà des frontières des Etats-Unis en cultivant des pousses sur des domaines privés.[23] La fondatrice du groupe, Connie Barlow (autrice d'ouvrages scientifiques populaires et « évangéliste évolutionnaire » auto-proclamée), est la co-autrice du premier article plaidant pour l'implémentation de projets de migration assistée, publié en 2004 avec le paléoécologue Paul Martin. Les auteurs affirment que le transfert de *Torreya taxifolia*, « le conifère le plus menacé au monde », est « aisé, légal et peu coûteux », et que les plantes en général font de bons partenaires pour ce type de projets parce qu'elles peuvent être replantées « hors de toute surveillance ou interdiction gouvernementale » - une opinion peu populaire au sein de la communauté conservationniste.[24]

Les Torreya Guardians sont généralement considérés comme peu sérieux et l'initiative a principalement servi de contre-exemple dans la littérature sur le sujet, mais leur projet est clairement indicatif d'une tendance plus vaste en conservation. Ainsi, en 2007, Mark Schwartz, Jessica Hellmann and Jason McLachlan ont publié un « cadre indicatif pour le débat sur la migration assistée » dans lequel les auteurs appellent à créer des mesures scientifiquement justifiées afin d'encadrer le transfert d'espèces menacées.[25] Les études bénéficiant de financements publics sont toutefois encore rares. Une première étude menée au Royaume-Uni a transféré deux espèces de papillons vers des sites supposés devenir plus favorables dans les années à venir sous l'effet du changement climatique.[26] Plus récemment, dans le cadre du projet CO-ADAPT mené entre

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[22] La thèse de Brian Keel, 'Assisted Migration as a Conservation Strategy for Rapid Climate Change: Investigating Extended Photoperiod and Mycobiont Distributions for Habenaria repens Nuttall (Orchidaceae) as a Case Study', fut déposée en 2007.

[23] Cf. Patrick D. Shirey et al., 'Commercial Trade of Federally Listed Threatened and Endangered Plants in the United States', *Conservation Letters* 6, no. 5 (1 September 2013): 300–316.

[24] Connie Barlow and Paul S. Martin, 'Bring Torreya Taxifolia North—Now', *Wild Earth*, 2004, 53.

[25] Cf. Jason S. McLachlan, Jessica J. Hellmann, and Mark W. Schwartz, 'A Framework for Debate of Assisted Migration in an Era of Climate Change.', *Conservation Biology: The Journal of the Society for Conservation Biology* 21, no. 2 (April 2007): 297–302.

[26] Stephen G. Willis et al., 'Assisted Colonization in a Changing Climate: A Test-Study Using Two U.K. Butterflies', *Conservation Letters* 2, no. 1 (1 February 2009): 46–52, 45.

2013 et 2015, cinq espèces de primevères ont été cultivées dans des parcelles expérimentales de jardins botaniques en Finlande, en Norvège et en Estonie.

Quand bien même les exemples concrets restent rares, la migration assistée a fait l'objet de nombreux débats, et un certain nombre de scientifiques travaillant dans des jardins botaniques sont actuellement occupés à réévaluer la robustesse de leurs collections si elles en venaient être utilisés dans le cadre d'un tel projet.

La migration assistée doit être analysée comme un élément dans la transformation de la formation de pouvoir spécifique à la biologie de la conservation. Les scientifiques qui défendent cette pratique soutiennent que la survie d'une espèce (et de la richesse biologique en général) ne peut plus être garantie par la défense d'un territoire délimité et reconnaissable. Ceci est un développement qui ressemble aux transformations diagnostiquées par Foucault dans ses écrits sur la gouvernementalité et la biopolitique : la biologie de la conservation a glissé de questions territoriales caractéristiques d'un pouvoir souverain à des efforts de sécurisation de populations typiques de la gouvernementalité, et se concentre désormais sur une « multiplicité » mouvante dont la circulation doit être régulée afin d'atténuer des risques prévisionnels.[27] Les questions posées depuis quelques années à propos de la viabilité de certains projets de migration assistée révèlent l'importance croissante d'une forme de sécurité circulatoire, que Foucault considère comme l'élément le plus important des relations de pouvoir néolibérales. Bien qu'il y ait déjà eu de nombreuses tentatives conservationnistes d'intervenir dans les milieux où circulent animaux et plantes sauvages, la discipline est maintenant confrontée à une difficulté supplémentaire, puisque ces milieux subissent des transformations allant au-delà de toute possibilité de prévision et de calcul.[28]

En faisant face à un environnement transformé au point d'en devenir potentiellement méconnaissable, la migration assistée semble converger progressivement avec certaines formes de bio- et de géo-ingénierie. Le langage employé dans la littérature scientifique semble volontairement vider les paysages dont il est question en les présentant comme des espaces ontologiquement et matériellement fluides pouvant accueillir des espèces transformées en migrants flexibles et entreprenants. Ce tournant rhétorique converge avec un renouveau de techniques

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[27] Michel Foucault, *Security, Territory, Population. Lectures at the Collège De France, 1977-78*, ed. Michel Senellart, trans. Graham Burchell (Basingstoke: Palgrave Macmillan UK, 2009), 171.

[28] Foucault, *Security, Territory, Population,* 95.

horticoles, puisque les jardins botaniques sont souvent les sites expérimentaux privilégiés de tests migratoires – une union apparemment paradoxale entre risque environnemental et stabilité imposée. La nature particulière de la migration assistée, située à la confluence de techniques de cultivation hautement régulées et d'une nouvelle forme de « gouvernance par le désordre », transforme certaines espèces menacées en agents mobiles et dotés de la capacité de recoloniser et de recréer de nouveaux espaces.

Ce tournant vers des ontologies ouvertes, vers l'incalculabilité des contingences environnementales et vers une gouvernementalité néolibérale doit toutefois être nuancé. Il est intéressant d'étudier ici un phénomène en particulier, à savoir l'émergence d'arguments ancrés dans une histoire évolutionnaire profonde et faisant appel à certains phénomènes de migrations préhistoriques conjointes d'humains et de plantes. En faisant appel à ces phénomènes, le discours conservationniste inscrit la migration assistée dans des dépendances de trajectoires (« path dependencies ») anciennes et vastes qui remettent en question la possibilité d'imaginer le monde comme entièrement contingent et fluide. Barlow, par exemple, affirme qu'une

> […] perspective temporelle profonde « deep time » pose de nouvelles questions : quelle aurait été l'aire de répartition indigène de l'espèce x durant une période interglaciaire – ou même une période plus ancienne (puisque certaines espèces de *Torreya* ont coexisté avec les dinosaures du Crétacé), dont le climat était plus chaud qu'il ne l'est maintenant ? […] Une perspective temporelle profonde permet de considérer un futur distant, et nous inspire le sentiment qu'il est urgent de repeupler le continent avec une mégafaune qui pourrait mener à la ré-évolution d'espèces véritablement *autochtones* à ce pays.[29]

Il est important de souligner que l'argument paléoécologique concernant les aires de distribution anciennes des espèces de *Torreya* a été critiqué et que la crédibilité scientifique de Barlow elle-même est controversée. Mais d'autres sources plus solides ont également souligné les histoires enchevêtrées de migrations humaines et nonhumaines, suggérant ainsi la possibilité de lire les pratiques de migration assistée comme des

[29] "A deep-time perspective thus opens up a new line of questioning: where would native range for species X have been during a peak interglacial — or during even more ancient times (species of genus Torreya coexisted with Cretaceous dinosaurs) when global climate was even warmer than it is today? […] A deep-time perspective, penetrating far into the future, invokes a felt urgency for humans to engage in repopulating this continent with megafaunal stock that may eventually re-evolve species truly *native* to this land.", Connie Barlow, "Deep Time Lags: Lessons from Pleistocene Ecology," in *Gaia in Turmoil. Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis*, ed. Eileen Crist and H. Bruce Rinker (Cambridge, Massachusetts: MIT Press, 2009), 169-71.

continuations de formes plus anciennes de capture réciproque et de devenirs communs. Par exemple, une étude récente concernant la migration assistée de certaines plantes par des populations préhistoriques Aborigènes d'Australie propose la conclusion suivante :

> En prouvant que des populations préhistoriques Aborigènes d'Australie ont dispersé des propagules de plantes afin de subvenir à leurs besoins et en ont tiré des bénéfices immédiats, nous problématisons également l'idée qu'il existe des distributions « naturelles » de plantes, et cela implique de réévaluer nos interprétations distributives quand elles ne prennent pas en compte l'impact d'interventions humaines préhistoriques. Les débats actuels autour de la question de migration assistée par les humains et autres propositions de gestion active pourraient également bénéficier d'une reconnaissance, de la part de conservationnistes et du public, que les peuples Aborigènes ont volontairement dispersés certaines espèces par le passé. Ceci est particulièrement important au vu du fait que nos critères pour évaluer le succès d'un projet de restauration écologique sont basés sur des références historiques (à savoir pré-Européennes).[30]

Voici donc deux exemples d'un courant sous-jacent dans cette littérature. Ici, nous voyons certains décalages temporels profonds servir de justification pour des projets de migration assistée ou de ré-ensauvagement, parce qu'ils permettent de transformer notre définition de ce qu'est une aire de distribution indigène. L'idée qu'en réalité nos écosystèmes ne sont *pas encore* adaptés à la perte leur mégafaune préhistorique ou que la configuration de nos écosystèmes actuels n'est due qu'au hasard des variations interglaciaires permet de transformer la migration assistée en technologie de stabilité plutôt que de mobilité. Ces espèces ne sont pas déplacées, mais bien plutôt rendues aux lieux dont elles viennent, les aires qu'elles occupaient durant une période plus ancienne. Elles ne cherchent pas à échapper à des conditions dégradées mais plutôt à revenir à leur pays natal ; c'est leur position actuelle qui est désormais considérée comme une anomalie.

[30] "Evidence of prehistoric Australian Aboriginal people dispersing plant propagules for their direct need and benefit also significantly challenges assumptions of "natural" plant distributions, requiring reassessment of distributional interpretations that omit the possible impact of prehistoric human intervention. Current debates on the role of human-assisted migration and other active management options could also benefit from the acceptance, from conservation practitioners and the general public, that Aboriginal people deliberately dispersed species in the past. This is particularly relevant since current measures of restoration success are often based on historical (pre-European) reference systems." Maurizio Rossetto et al., 'From Songlines to Genomes: Prehistoric Assisted Migration of a Rain Forest Tree by Australian Aboriginal People', ed. Renee M. Borges, *PLOS ONE* 12, no. 11 (8 November 2017): e0186663, 12.

La question qui se pose alors est la suivante : que sont ces récits de migration communes, sinon des manières de narrer de nouvelles cosmo-écologies ? Je propose de lire ces éléments rhétoriques comme autant de tentatives – certes partielles et instables – de resituer des pratiques conservationnistes dans la continuité de collaborations multi-espèces, et de reconstituer un stock d'exemples et d'images dans lequel le discours conservationniste pourrait puiser. Ces biologistes et écologistes font référence à une histoire évolutionnaire et humaine qu'ils recomposent et réinterprètent, ce qui leur permet de spatialiser le temps et de négocier avec des conditions environnementales de plus en plus instables. L'argument selon lequel certains espaces ont été désignés comme foyers par d'anciennes collaborations inter-espèces est aussi une façon de redessiner la frontière entre le vivant et le mort, puisqu'il complique les mécanismes sacrificiels conservationnistes selon lesquels ce qui est invasif et indésirable est considéré comme quasiment déjà mort. Ici, ne pas être à sa place n'implique plus nécessairement d'être destiné à être extirpé, à condition qu'il existe un récit cohérent pouvant justifier cette position géographique. Je vois aussi, dans cette réorientation du discours conservationniste, l'émergence potentielle d'une vision du monde basée non sur des trajectoires linéaires mais sur des temporalités qui peuvent être contractées, réassemblées, organisées en cycles plus vastes que ceux des saisons ou de générations. Le passé de ces plantes devient leur futur, une orientation temporelle qui est non sans rappeler celles du peuple Yarralin dont parle Deborah Bird Rose dans son livre *Reports From a Wild Country*, dont les ancêtres précèdent les descendants et marchent au-devant d'eux dans le temps du rêve et dont la trajectoire est de se rapprocher du passé plutôt que de s'en éloigner.[31] Bien qu'il serait facile de proposer une lecture cynique de ce discours comme justification propagandiste, il est intéressant de considérer ce type de projet transformatif comme une forme de cosmologie ou de folklore en cours d'élaboration dans laquelle certains scientifiques oscillent sans cesse entre des stratégies rhétoriques explicites et les effets de ces stratégies, qui peuvent parfois dépasser leurs attentes et calculs individuels.

Chapitre 2. « Il sera nécessaire de transformer notre pensée agricole » : la conservation d'espèces sauvage cousines

[31] Cf. Deborah Bird Rose, *Reports from a Wild Country: Ethics for Decolonisation* (Sydney: University of New South Wales Press, 2004).

Le second cas d'étude examiné ici est la conservation d'espèces sauvages cousines de plantes cultivées, et en particulier le Crop Wild Relatives Project de la Millennium Seed Bank du jardin botanique royal de Kew. Les espèces sauvages cousines (« crop wild relatives », ou CWR) dont la définition inclut « tout taxon sauvage ayant une utilité indirecte dû à sa relation génétique étroite avec une plante cultivée », ont longtemps proliféré aux marges géographiques et institutionnelles de nombreux systèmes agricoles. Ces plantes ont souvent été mobilisées à des fins de cultivation, notamment afin de combattre des épidémies destructrices telles que le tristement célèbre mildiou des pommes de terre au XIXe siècle. L'usage qui en a été fait dans ce type de projets est intimement lié aux trajectoires conjointes du colonialisme extractiviste, des vastes mouvements de populations humaines et nonhumaines que ce dernier a imposés, et de la propagation de ce qu'Anna Tsing nomme « écologies simplifiées ». Tsing désigne par ce nom le mode particulier de gestion et de production de valeur ajoutée que nous avons hérités de plantations coloniales, et qui forment encore la base de la grande majorité de nos systèmes agricoles. Ceux-ci sont majoritairement composés de monocultures intensément vulnérables aux flux de pathogènes et de parasites que nos systèmes de transport globalisés ont grandement facilités.[32]

La raison pour laquelle ce cas d'étude figure dans une thèse traitant de la conservation d'espèces sauvages est qu'un seuil décisif a récemment été franchi dans la conservation d'espèces sauvages cousines en termes d'ampleur et de l'utilisation à laquelle elles sont destinées. Ces plantes sont depuis longtemps conservées dans un certain nombre de banques de graines agricoles, mais de nombreux scientifiques se sont tournés récemment vers les jardins botaniques, arguant que ces institutions pourraient faire de bons alliés. Ces efforts se sont soldés par l'inauguration, en 2011, d'un vaste projet intitulé « Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives », également connu sous le nom de Crop Wild Relatives Project. Financé à hauteur de 50 millions USD par le gouvernement norvégien, le projet est géré conjointement par le Crop Trust et la Millennium Seed Bank, en collaboration avec de

[32] Cf. Anna Lowenhaupt Tsing, 'A Threat to Holocene Resurgence Is a Threat to Livability', in *The Anthropology of Sustainability Beyond Development and Progress*, ed. Mark Brightman and Jerome Lewis (New York: Palgrave Macmillan, 2017).

nombreuses banques de graines à travers le monde.[33] Les 24 pays partenaires du projet conduisent leurs propres expéditions de collecte ; chaque banque de graines locale garde la moitié du matériau accumulé et envoie la seconde moitié à la MSB. Ces graines sont ensuite envoyées à des banques spécialistes de chaque espèces afin de germiner et multiplier chaque échantillon et de produire une quantité de graines suffisante pour des projets d'hybridation ; ensuite vient le processus de pré-cultivation, dans lequel ces espèces sauvages sont hybridées avec des plantes cultivées et les hybrides cultivés dans des conditions expérimentales afin de déterminer si ils possèdent certaines caractéristiques leur permettant de mieux résister à la sécheresse, à la chaleur ou à certains parasites que leurs parents.

Ce qui m'intéresse ici sont les effets plus vastes de ce projet sur les institutions et pratiques conservationnistes, et en particulier sur les façons de collecter, de hiérarchiser et d'utiliser certaines graines sauvages maintenant que ces collections sont évaluées à travers un prisme agricole. Les chercheurs et cultivateurs impliqués dans ce projet gèrent une population composée de sujets hétérogènes appartenant à deux catégories distinctes – espèces sauvages et domestiquées – qui doivent désormais entrer en coopération. Cette fusion de deux logiques biopolitiques voisines mais structurellement différentes est au cœur du statut ambigu des espèces sauvages cousines, qui existent dans l'interstice entre sujets politiques et objets exploitables.

Ceci est particulièrement évident dans les définitions apparemment contradictoires de leur vulnérabilité et de leur résilience proposées dans la littérature scientifique : les espèces cultivées sont vulnérable parce que trop adaptées à une société industrialisée, les espèces sauvages cousines le sont parce trop peu adaptées à ces mêmes conditions ; les espèces cultivées sont résilientes parce qu'elle bénéficient du soin et de l'attention que leurs apportent leurs cultivateurs, et les espèces sauvages parce qu'elles ont eu la possibilité de se confronter librement à une vaste variété de menaces biotiques et climatiques. L'espace qu'il s'agit maintenant de gérer est cet interstice différentiel entre catégories de plantes, et la forme de pouvoir caractéristique de ce projet ne porte pas *sur* une espèce particulière ni même sur une catégorie d'espèces, mais est exercée *à travers* les relations entre espèces.

[33] Cf. Hannes Dempewolf et al., 'Adapting Agriculture to Climate Change: A Global Initiative to Collect, Conserve, and Use Crop Wild Relatives', *Agroecology and Sustainable Food Systems* 38, no. 4 (21 April 2014): 369–77.

Les effets de cette transformation ne s'arrêtent toutefois pas à la façon dont les espèces sauvages cousines sont assujetties et traitées ; comme le soutiennent par exemple Dominique Lestel et Vinciane Despret, le fait de collaborer avec des autres nonhumains dans un cadre expérimental transforme également les expérimentateurs humains. La méthode proposée par Frédéric Keck dans ses travaux sur la lutte contre les pandémies est un guide utile lorsqu'il s'agit de comprendre quelles sont les nouvelles figures qui prolifèrent autour de la collecte et de la gestion d'espèces sauvages cousines. Ici, je m'intéresse tout particulièrement à la distinction faite par Keck entre le stockage ordinaire (d'échantillons viraux) et le stockage de biens prioritaires (tels que les vaccins contre la grippe aviaire), associés respectivement à des logiques cynégétiques et pastorales – une distinction qui s'applique également à la collecte et à la cultivation d'espèces sauvages cousines. Ces deux formes de stockage sont, d'après Keck, des « modes de production de valeur ajoutée biologique » et fonctionnent comme techniques d'anticipation. Le stockage de biens prioritaires transforme des ressources naturelles en ressources sociales en imaginant une pénurie au niveau de la société. Le stockage ordinaire, au contraire, répond à une pénurie supposée naturelle, et cherche à préserver « toutes sortes d'outils et de matériaux, dans la mesure où ils peuvent être utilisés à des fins diverses. »[34] Ceci conduit Keck à formuler l'hypothèse suivante :

> Les techniques de collecte et de préservation de microbiologistes sont peut-être plus proches de celles de chasseurs virtuoses, qui traquent les mouvements d'animaux et tracent leurs relations de parenté, que de celles d'entreprises pharmaceutiques.[35]

Cette définition peut également être appliquée aux pratiques de collecte de graines pour le Crop Wild Relatives Project. Sebastien Carpentier, un ingénieur bioscientifique et pré-cultivateur associé au projet, raconte ainsi dans un entretien au titre pertinent ("Hunting for Drought Tolerance in Papua New Guinea") l'expédition qu'il a menée en Papouasie-Nouvelle Guinée afin de trouver de nouvelles espèces de bananes sauvages plus résistantes à la sécheresse. Durant cette expédition, devenue nécessaire en raison des difficultés rencontrées au moment de faire germer les graines envoyées par la MSB,

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[34] Frédéric Keck, 'Stockpiling as a Technique of Preparedness: Conserving the Past for an Unpredictable Future', in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017), 135-136.

[35] Keck, 'Stockpiling as a Technique of Preparedness', 136.

l'équipe de Carpentier n'était pas tant à la recherche de nouvelles espèces en particulier que d'un éventail variable de traits au sein de ces espèces. Afin de mener cette recherche à bien, il leur a fallu passer par un processus d'adaptation très fine à leur environnement et développer la capacité de traquer certains individus adaptés à des niches spécifiques.

Nous retrouvons cette manière de formuler des hypothèses sur une espèce et son environnement, caractéristique de l'échange de perspectives que Keck considère comme élément fondamental des pratiques cynégétiques,[36] dans un autre projet de recherche et de collecte. Tamrat et al. ont ainsi conduit des test de germination sur vingt échantillons domestiqués et sauvages d'*Ensete ventricosum* (aussi connu sous le nom de bananier d'Abyssinie) collectés en Éthiopie, et ce afin de reconstituer des mécanismes de reproduction sexuée dont nous avons perdu la connaissance en cultivant cette plante de façon presque exclusivement végétative. Le travail de terrain de cette équipe de chercheurs implique de traquer certains signes d'interactions potentielles qui pourraient fournir des indices quant au comportement sexuel de ces plantes. Les auteurs de l'article indiquent qu'ils « n'ont pas trouvé de preuves que certaines variantes ont perdu la capacité de fleurir, ce qui est en accord avec les opinions de fermiers [locaux] », et observent que la continuité de formes de reproduction sexuées pourrait être assurée entre autres par l'habitude qu'ont les fermiers les plus aisés de la région de laisser fleurir un plant d'*Ensete ventricosum* ornemental sur leur domaine plutôt que d'en faire la récolte.[37] Au cours de cette étude, les auteurs formulent de nombreuses autres hypothèses à propos des interaction inter-espèces qui pourraient avoir façonné les variantes sauvages et domestiques d'*Ensete ventricosum*, un processus exigeant un certain degré d'identification avec ces plantes et la capacité de comprendre leurs relations avec d'autres espèces de leur point de vue. En cela, leur méthode ressemble également à ce que Norman Ellstrand appelle le travail de détective entrepris par les scientifiques tentant de comprendre la chronologie de certaines introgressions ayant eu lieu entre espèces sauvages et cultivées.[38]

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[36] Cf. Keck, Frédéric Keck, *Avian Reservoirs: Virus Hunters and Birdwatchers in Chinese Sentinel Posts* (Durham: Duke University Press, 2020).

[37] Solomon Tamrat et al., 'Germination Ecology of Wild and Domesticated Ensete Ventricosum: Evidence for Maintenance of Sexual Reproductive Capacity in a Vegetatively Propagated Perennial Crop', *BioRxiv*, preprint, May 2 2020.

[38] Cf. Norman C. Ellstrand, *Dangerous Liaisons? When Cultivated Plants Mate with Their Wild Relatives* (Baltimore: John Hopkins University Press, 2005).

Il semblerait donc que la nécessité de chorégraphier de nouvelles relations dans un contexte expérimental transforme parfois les scientifiques de la MSB et de ses institutions partenaires en chasseurs, en particulier lorsqu'ils s'aventurent dans les marges férales où prolifèrent les espèces sauvages cousines. Je considère cette transformation comme signe que ce projet de conservation institue une cosmologie dans laquelle le concept de *domestication* fonctionne simultanément en tant que dispositif ordonnateur et catégorie contestée et constamment renégociée. Les zones frontalières dans lesquelles s'aventure le Crop Wild Relatives Project sont des espaces dans lesquels la domestication n'est jamais un processus achevé, ou même enclenché ; dans cet espace, conservateurs et biologistes doivent reprendre les premières étapes de l'apprivoisement et de la capture réciproque avant même de pouvoir prétendre à redevenir cultivateurs.

Je me base ici sur un autre texte anthropologique, à savoir le récit fait par Jon Remme de ses observations de terrain à Ifugao, dans les Philippines. Observant les relations entre humains et cochons, Remme montre que de nombreuses formes de domestication peuvent coexister et qu'elles « ont lieu dans un champ relationnel plus vaste qu'on ne le présume souvent ».[39] A Ifugao, les cochons sont vus à travers une grille cosmologique dans laquelle ils peuvent être traités comme domestiqués ou sauvages selon la situation et le contexte. Chaque foyer élève et nourrit des cochons « domestiques » à des fins sacrificielles, et certains rituels de guérison demandent de mettre en scène des chasses durant lesquelles ces cochons sont transformés en animaux sauvages afin d'être rendus aux esprits. Réciproquement, les cochons « sauvages » qui peuplent la forêt sont parfois chassés, mais ils doivent d'abord être rituellement reconnus comme la propriété domestique des esprits vivant dans la forêt. Remme met ainsi au défi l'idée que la domestication représente nécessairement une transformation profonde, unilinéaire et irréversible des relations entre humains et animaux. Le domestique et le sauvage, d'un point de vue cosmologique, sont une question de propriété, de perspective et de position.

J'en conclus que le Crop Wild Relatives Project ne représente pas uniquement la confirmation d'une histoire multi-espèces solidement basée sur des processus de domestication. Au contraire, ce projet permet aux chercheurs de la MSB et de ses

[39] Jon Henrik Ziegler Remme, 'Pigs and Spirits in Ifugao: A Cosmological Decentering of Domestication', in *Domestication Gone Wild: Politics and Practices of Multispecies Relations*, ed. Heather Anne Swanson, Marianne E. Lien, and Gro Ween (Durham: Duke University Press, 2018), 51.

institutions partenaires de mener pas à pas de nouveaux processus de domestication dont le résultat n'est jamais garanti. Ce qu'il s'agit d'assurer ici est la possibilité d'une circulation catégorielle continue, de l'émergence future d'interactions positionnelles. Tout comme les cochons d'Ifugao, dont l'efficacité rituelle dépend de la possibilité de se mouvoir entre foyer et forêt, les espèces sauvages cousine ne demeurent utiles que tant qu'elles peuvent librement circuler d'un régime domesticatoire à une logique du sauvage et vice-versa. Si les marges entre le domestique et le sauvage, où ces plantes peuvent se rencontrer et parfois interagir, en venaient à être entièrement colonisées, le projet même de cultiver des hybrides résistants serait compromis, puisque le seul processus pouvant assurer la production future de traits utiles en agriculture est l'évolution continue de plantes sauvages dans leur environnement naturel. La conservation d'espèces sauvages cousines révèle ainsi l'importance cruciale de processus contemporains de domestication, et à quel point il est important de les nommer comme tels : ils mettent en scène des pratiques qui impliquent non seulement de transformer certains nonhumains et leurs capacités, mais aussi de renégocier ce que la domestication elle-même est, devrait être, ou pourrait devenir.

Chapitre 4. « Un océan futur en constante évolution » : l'évolution assistée de coraux

L'adaptation à des conditions environnementales nocives est une question débattue depuis longtemps en conservation, en particulier lorsqu'il s'agit de l'intégration de l'élevage en captivité dans des programmes de conservation (un processus enclenché notamment avec la création des Species Survival Plans par la American Association of Zoological Parks and Aquaria dans les années 1980 et l'instauration subséquente d'un système de livre généalogiques et de procédures de reproduction coordonnées entre zoos).[40] L'élevage en captivité cristallise trois anxiété conservationnistes distinctes mais connexes : le problème du maintien de populations sauvages aussi « pures » que possible, l'habituation excessive aux habitats captifs, et la question de comment réadapter les individus destinés à être réintroduits dans un habitat sauvage. Après une période de

[40] Cf. par exemple Jesse Donahue and Erik Trump, *The Politics of Zoos: Exotic Animals and Their Protectors* (DeKalb: Northern Illinois University Press, 2006; Éric Baratay and Elisabeth Hardouin-Fugier, *Zoo: A History of Zoological Gardens in the West* (London: Reaktion Books, 2002).

débats et de critiques dans les années 1990, l'idée de procéder à l'élevage sélectif d'espèces sauvages afin de les rendre plus résistantes à certaines menaces environnementales a connu un certain renouveau dans la littérature conservationniste. Venesky et al., par exemple, affirment que

> Quand certaines espèces ne peuvent survivre dans leur habitat naturel à cause d'un pathogène ou d'un herbivore introduit [par l'homme], nous utilisons souvent des outils de conservations tels que l'élevage en captivité afin de réduire le risque d'extinction. L'introduction d'individus élevés en captivité dans leur habitat naturel ou leur transfert vers une autre aire considérée comme un habitat approprié est un élément inhérent à toute pratique d'élevage en captivité. La sélection artificielle est souvent un outil important de ces programmes au vu du fait que la sélection naturelle pourrait être trop lente à protéger ces espèces de nouveaux pathogènes ou herbivores.[41]

C'est dans ce contexte que l'idée de renforcer des populations menacées de goulot d'étranglement génétique en introduisant des « migrants » est devenue de plus en plus acceptable. Le cas de la panthère de Floride en est l'exemple le plus cité : en 1995, huit femelles pumas importées du Texas furent introduites dans une population de panthères de Floride afin de revitaliser la diversité génétique de ces dernières, une intervention dont le résultat fut de « multiplier le nombre de panthères par trois, de doubler d'hétérozygotie de leurs gènes, d'améliorer leurs statistiques de survie et de valeur sélective, et de diminuer les signes de consanguinité ».[42]

Le domaine de la conservation des amphibiens, quant à lui, a vu la naissance d'un projet d'élevage sélectif dans l'espoir de contrer les effets ravageurs d'un pathogène fongique (le *Batrachochytrium dendrobatidis*) ; des études pilotes ont été menées au Voyles Lab de l'Université du Nevada et au Center for Species Survival de la Smithsonian Institution. Mais c'est en conservation marine que l'évolution assistée a véritablement

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[41] "When species are unable to survive in their natural habitat because of an introduced pathogen or herbivore, conservation efforts, such as captive breeding, are often used to reduce the threat of extinction. The eventual introduction of captive-bred individuals to their natural habitat or their translocation to another area thought to be sufficient habitat is an inherent element of captive breeding programs. Artificial selection in captive breeding programs is often an important tool because natural selection may not occur fast enough to protect hosts from rapid exposure to novel pathogens or herbivores," Matthew D. Venesky et al., 'Selecting for Tolerance against Pathogens and Herbivores to Enhance Success of Reintroduction and Translocation: Tolerance against Pathogens and Herbivores', *Conservation Biology* 26, no. 4 (August 2012): 586–92, 587. Cf. également Colin Tudge, *Last Animals at the Zoo: How Mass Extinction Can Be Stopped* (Washington, Covelo, London: Island Press, 1992).

[42] Warren E. Johnson et al., 'Genetic Restoration of the Florida Panther', *Science* 329, no. 5999 (24 September 2010): 1641–45, 1641.

émergé comme projet de recherche cohérent. La création de coraux « cultivés pour le futur », loin d'être une proposition théorique, est actuellement pratiquée dans plusieurs laboratoires à travers le monde.[43] L'un d'entre eux est le National Sea Simulator, un centre de l'Australian Institute of Marine Science (AIMS) situé à Townsville, dans le Queensland. Ce laboratoire a accueilli à ce jour deux projets d'évolution assistée, portant respectivement sur des croisements intraspécifiques et sur des hybridations interspécifiques. Pour le premier projet, dirigé par Line Bay, des coraux de l'espèce *Acropora millepora* ont été importés depuis le nord du Queensland, où la Grande Barrière a été touchée par les vagues de chaleur océaniques de 2016 et 2017. Après avoir testé ces coraux et déterminé qu'ils possèdent désormais une résistance à des températures plus élevées, l'équipe de Bay les a croisés avec des individus prélevés au milieu du récif, où les températures sont plus basses. Les juvéniles nés de ce croisement ont été replantés sur la Grande Barrière en 2019 afin de déterminer si la diversité génétique dont ils ont hérité leur permettent de mieux survivre au réchauffement océanique.[44] Pour le second projet, dirigé par Madeleine Van Oppen, plusieurs paires d'espèces ont été croisées afin de déterminer si des coraux hybrides pourraient potentiellement se montrer plus adaptés à des conditions dégradées en termes de températures, d'acidité ou de salinité.[45]

Les coraux sont particulièrement bien adaptés aux nouveaux laboratoires hybrides que nous voyons apparaître au cours des mutations du paysage conservationniste ; leurs particularités physiologiques, sociales et reproductives leur permettent de fonctionner comme partenaires privilégiés de projets d'élevage sélectif. L'émergence de coraux en tant que site où les pratiques et discours de l'Anthropocène sont formés, testés et contestés n'est pas entièrement nouvelle : comme le montre la chronologie de figurations coralliennes établie par Stefan Helmreich, ils ont depuis deux siècles au moins permis d'« habituer ceux qui les visitent et qui s'intéressent à eux à des questions empiriques et expérimentales d'échelle et de contexte ».[46] Après avoir tracé l'histoire de récifs coralliens comme figure métaphorique prisée par les anthropologues désireux d'expliquer l'émergence et le fonctionnement de sociétés au XIXe siècle, puis

[43] Ruth Gates, citée dans *Creating 'Super Coral' to Save Dying Coral Reefs*, 2015, https://www.youtube.com/watch?v=DtCDquEYzPE.

[44] Cf. "Next Generation Corals Undergo First Field Tests on the Great Barrier Reef," *AIMS*, 2 July 2019.

[45] Cf. Wing Yan Chan et al., "Interspecific Hybridization May Provide Novel Opportunities for Coral Reef Restoration," *Frontiers in Marine Science* 5 (14 May 2018): 160.

[46] Stefan Helmreich, "How Like A Reef. Figuring Coral, 1839–2010," dans *Sounding the Limits of Life: Essays in the Anthropology of Biology and Beyond* (Princeton: Princeton University Press, 2016), 49.

leur transformation en représentants de formes non-hétéronormatives, distribuées et translocales de reproduction, Helmreich note qu'ils sont désormais étudiés en tant que porteurs de génomes. L'utopie queer qu'est le récif corallien est maintenant intensément menacée, et de nombreux écologistes considèrent ces écosystèmes comme des indicateurs importants de changements climatiques. En parallèle, le récif est en cours de transformation en ressource biomédicale : les toxines produites par certains coraux pourraient être utilisées afin de mettre au point des traitements centre le cancer et le VIH. Ces deux rôles nouvellement endossés par les coraux au XIXe siècle sont liés à l'essor de la recherche génétique dans le domaine de la science marine. La question de savoir quelle espèce de corail devrait servir d'organisme modèles et de rat de laboratoire a été posée lors de discussions concernant la possibilité de monter un « Coral Genome Project ». Les deux candidats principaux pour un tel projet sont l'espèce *Porites lobata* et le genre *Acropora*, dont sont issues les espèces hybridées par Van Oppen dans les laboratoires du AIMS.[47]

Il semblerait que ces laboratoires héritent au moins en partie du tournant génétique de la biologie marine, au sens où le projet de Van Oppen traite parents et descendants hybrides comme un ensemble de fonctions et de performances mesurables. Dans l'étude observant l'adaptation des hybrides élevés depuis 2015 au AIMS et servant de « démonstration de faisabilité » du projet, chaque étape est décrite comme l'occasion de purifications scrupuleuses. Les colonies parentales collectées à Trunk Reef sont « isolées dans des aquariums individuels afin d'éviter le mélange non contrôlé de gamètes avant les croisements in vitro » lorsque vient le moment de la ponte. Ensuite, ovules et spermatozoïdes sont soigneusement séparés et lavés; une fois les larves juvéniles établies dans leurs aquariums, les algues symbiotiques nécessaires à leur survie sont étroitement contrôlées afin que les hybrides ne reçoivent que des symbiontes associés à leurs espèces parentales.[48] Leur capacité à survivre dans des conditions défavorables (à savoir des aquariums aux températures et taux de CO_2 plus élevés que ceux du groupe contrôle) est ensuite observée en mesurant « quatre traits phénotypiques (survie, taille, assimilation

[47] Helmreich, "How Like a Reef," 58-59.
[48] Chan et al., "Interspecific Hybridization," 3 and 5.

de *Symbiodinium* et efficacité photochimique) […] fonctionnant comme indicateurs de la *fitness* des hybrides et des descendants de la même espèce ».[49]

Le Sea Simulator, un laboratoire produisant volontairement des créatures nouvelles et fonctionnant sur des principes d'innovation technologique, semble donc impliqué dans un processus de réification. Dans un entretien, Van Oppen me dit qu'un des buts de l'évolution assistée est de conserver au moins une partie du génome de ces espèces dans des individus plus résistants, « même si ce sont des hybrides » ; elle reconnaît que cette pratique de conservation n'est ni idéale ni suffisante, mais note qu'elle est néanmoins préférable à la perte définitive de ces espèces.[50] De ce point de vue, l'élevage de coraux hybrides semble transformer ces organismes en simples contenants d'information génétique, et par là même substituer à un ensemble de relations hétérogènes complexes un objet fixe qui pourrait être la source de sa propre valeur – en d'autres mots, une marchandise fétichisée.[51]

Une telle critique risque toutefois d'ignorer les conditions matérielles dans lesquelles ces hybrides sont étudiés et entretenus, et doit donc être nuancée. Comme l'a montré Donna Haraway, un laboratoire n'est jamais uniquement un espace réductionniste ; c'est aussi un lieu de production matérielle et sémiotique d'entités technoscientifiques qui peuvent être multiples, interagir, et faire monde, « nous obligeant à réévaluer ce qui compte comme nature et comme artefact, et quelles histoires seront refoulées, par qui et pour qui. »[52] Dans les laboratoires accueillant des projets d'évolution assistée s'élabore une pratique dont certains éléments résistent aux tendances réificatrices du tournant génétique en biologie marine. Il est important ici de noter que le Sea Simulator est destiné à n'être qu'un lieu de passage transitoire pour les coraux hybrides. Durant notre entretien, Van Oppen me rappelle qu'actuellement, son équipe ne cultive ces hybrides que pour une génération. L'une des explications est que le coû t engendré par la gestion de plusieurs générations de coraux, mettant toutes plusieurs années à atteindre leur maturité sexuelle, serait bien trop élevé. Mais elle cite une deuxième raison : « nous

[49] "four phenotypic traits (i.e., survival, recruit size, *Symbiodinium* uptake, and photochemical efficiency) […] in hybrid and purebred offspring as proxies for fitness." Chan et al., "Interspecific Hybridization," 3.

[50] Madeleine Van Oppen, entretien, 28 september 2020.

[51] Cf. Donna Haraway, *Modest_Witness@Second_Millennium. FemaleMan_Meets_OncoMouse: Feminism and Technoscience* (New York and London: Routledge, 1997).142-144.

[52] "[…] forcing a revaluation of what counts as nature and artifact, of what histories are to be inhibited, by whom, and for whom." Haraway, *Modest Witness*, 119.

nous retrouverions avec des coraux qui seraient – disons, qui pourraient avoir été domestiqués et dont la capacité à survivre dans la nature serait diminuée ».[53]

L'évolution assistée n'est donc pas motivée uniquement par une volonté de contrôle et de réduction ; l'extension totale de la maîtrise humaine doit être sans cesse limitée afin de ne pas risquer l'adaptation trop complète de ces coraux à leur environnement expérimental. S'il est vrai que les coraux sont devenus progressivement plus transparents aux technologies génétiques, ils subissent également certaines transmutations épistémologiques qui les rendent plus denses, les transformant en un ensemble foisonnant de procès que la biologie marine ne saisit pas encore entièrement et qui peuvent être difficiles à isoler à des fins d'observation scientifique. Les mécanismes reproductifs coralliens en particulier ont fait l'objet d'un tournant épistémologique et expérimental important. La particularité des coraux scléractiniaires est de pouvoir passer d'un régime reproductif à un autre selon le dispositif scientifique ou économique dans lequel ils sont intégrés. Dans le domaine de la restauration écologique et de l'élevage économique, les coraux sont normalement propagés de façon asexuée – par boutures, comme des plantes. Les projets d'évolution assistée sont un des rares domaines dans lesquels la reproduction sexuée de coraux, coûteuse en argent et en temps, s'est imposée comme technologie incontournable.

Cette importance nouvelle d'une forme de reproduction sexuée (associée dans le langage de certains scientifiques à un devenir-animal de ces espèces d'*Acropora*) pourrait apparaître comme un renforcement problématique de hiérarchies biologiques plaçant les capacités animales au-dessus du végétal en termes de biopolitique reproductive. Mais il est important de souligner que ce qui est visé en évolution assistée est non un comportement sexuel « animal » universel mais plutôt la figure de l'animal telle qu'elle a été construite dans les jardins zoologiques, à savoir un ensemble d'animaux reconnus comme individus et dont les généalogies peuvent êtres documentées et tracées. « Animal » ne désigne pas ici un degré de supériorité ontologique ou comportementale mais bien plutôt une forme de parenté traçable, la possibilité de différence par recombinaison, et la mobilisation de certaines formes d'hérédité. L'espace expérimental créé au sein de l'AIMS, dans lequel l'enchevêtrement de coraux et d'humains est limité par des frontières activement maintenues, rend possible l'élaboration de nouvelles manières

[53] Madeleine Van Oppen, entretien, 28 septembre 2020.

de *travailler* ensemble, de former des relations qui vont devoir survivre en dehors des conditions contrôlées de l'aquarium.

Ce qui est produit dans ces projets d'évolution assistée est ainsi potentiellement à l'opposé des naturalisations stratégiques qui structurent les deux cas d'études précédents. En présentant le travail et la collaboration de coraux comme des phénomènes historicisés pouvant faire l'objet d'études écologiques et de recherches expérimentales, ce projet dénaturalise potentiellement *toute* forme de travail reproductif et métabolique. Cette lecture est basée en partie sur le travail de Sophie Lewis autour de la question des technologies reproductrices et de gestation pour autrui, en particulier sa manière de théoriser ce qu'elle nomme « géographie utérine ». Lewis démontre qu'une analyse des sites, technologies et corps impliqués dans le travail de gestation au sens large nous permet de saisir le « caractère contingent et artificiel mais également *conscient* et fragile de la parenté, de l'identité et de la filiation », et de voir non seulement la gestation pour autrui mais aussi tout autre acte de gestation et de travail reproductif comme fondamentalement non-naturel.[54] C'est en tant que lieux de gestation pour autrui – de *surrogacy* – que les laboratoires accueillant des projets d'évolution assistée produisent un savoir qui historicise et contextualise ce que les coraux sont supposés faire « naturellement », révélant la structure complexe de récifs coralliens comme le résultat fragile de labeur, de lignées et de traditions nonhumaines qui doivent être activement maintenues.

Plutôt que de naturaliser certaines interventions dans des processus nonhumains (une stratégie présente dans la littérature sur la migration assistée et la conservation d'espèces sauvages cousines), l'évolution assistée mobilise un concept remanié du sauvage, désormais vidé de ses connotations romantiques d'indépendance ou de pureté ; mais elle ne verse pas pour autant dans l'autre extrême, à savoir ce que Carrie Friese appelle les espèces 2.0, entièrement reconstruites et attestant de la puissance et de l'inventivité humaines.[55] Les négociations prudentes nécessaires quand il s'agit de gérer ces sujets fuyants que sont les coraux, ainsi que leur propension à s'adapter un peu trop rapidement au laboratoire et leur capacité à s'engager dans des formes de collaboration

[54] "[…] the contingent and artificial but also *conscious* and fragile character of kinship, identity and relatedness" Sophie Lewis, "Cyborg Uterine Geography: Complicating "Care" and Social Reproduction," *Dialogues in Human Geography* 8, no. 3 (November 2018): 300–316, 307.

[55] Carrie Friese, *Cloning Wild Life: Zoos, Captivity and the Future of Endangered Animals.* (New York: New York University Press, 2013), 91.

multiples, pourraient offrir un modèle intéressant pour penser ce que Baptiste Morizot appelle une « interdépendance équilibrée » entre espèces.[56] Quand la conservation transformatrice se présente comme une intervention permettant d'animer l'*agency* matérielle et temporelle de certaines espèces menacées, il devient possible de voir ce que l'acte de survivre en évoluant, en particulier en période d'extinction de masse, n'a peut-être *jamais été naturel*. Procéder à une analyse critique de ces pratiques de conservation spéculatives ne signifie pas tant condamner leur artificialité en la présentant comme rupture violente de l'ordre naturel des choses, mais bien plutôt de caractériser plus précisément la nature du travail que ces pratiques proposent d'entreprendre, et d'évaluer leur capacité à collaborer ou non avec certaines formes nonhumaines de travail et de maintien de liens de parenté.

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[56] Cf. Baptiste Morizot, "Le Devenir Du Sauvage à l'Anthropocène", in *Comment Penser l'Anthropocène?*, ed. Rémi Beau and Catherine Larrère (Paris: Presses de Sciences Po, 2018), 249–64.

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Introduction

> "In short, Anthropocene-thinking requires the practice of a radical form of ontological pluralism, both on the side of anthropology— the attention to the many ways of living and thinking the Anthropocene by different peoples in different places, differently affected by capitalism's processes of material extraction and spiritual sorcery—and on the side of the ecological, biological, and geophysical sciences—unearthing the "different Earths"; mapping out of different zones of ecological simplification; recording the sometimes surprising unintentional effects of bio-, socio-, and geo-engineering actions on the part of states and corporations; developing the new insights about the multifarious symbiotic interdependence of all life-forms."

— Eduardo Viveiros de Castro, "On Models and Examples: Engineers and Bricoleurs in the Anthropocene"

In 2014, the conference of the Western Society of Naturalists welcomed two speakers whose antagonism had been long in the making. Michael Soulé, one of the founding figures of conservation biology, and Peter Kareiva, a figurehead of the "new conservation" movement, were to appear on the first morning. The general expectation seemed to be that they would each mention the ongoing debate about the future of conservation biology which Keith Kloor, the journalist who reported on this meeting for the magazine *Issues in Science and Technology*, grandiosely characterises as the "battle for the soul of conservation science".[1] While their respective conference presentations were reported to ultimately skirt the most divisive issues, the expectation of a square-off is representative of the critical transformations that conservation biology as a whole is undergoing at the moment.

One of the many questions dividing traditional and new conservationists is the degree to which the resilience of species and ecosystems can ensure their adaptation to new and destructive environmental conditions, and to what extent conservation biology should not only accept but integrate change and novelty. New conservationists, and a number of popular science writers, are arguing for a hopeful reading of Anthropocene

[1] See Keith Kloor, "The Battle for the Soul of Conservation Science", *Issues in Science and Technology* 31, no. 2 (2015): 74–79.

disturbances and the genetic and ecosystemic novelty they bring. Hybridisation, new forms of speciation, the formation of novel ecosystems have all been lauded as signs that, perhaps, environmental catastrophes can be generative of new ways of living and flourishing together – at least for those species entrepreneurial enough to take advantage of these newly formed niches.[2] This debate has converged with the transformation of available conservation technologies, extending the possibilities for human intervention in the processes of plant and animal biology.

The starting point of this thesis was an interest in the conservation of endangered wild species ex situ (in institutions such as zoos and botanical gardens, be it as captively bred populations of plants and animals or seed banks and frozen gamete collections), and in unraveling the contradictions inherent to the static preservation of the agentive and responsive organisms that are plants and animals in captivity in an increasingly unstable world. Researching the practices and technologies of ex situ conservation quickly revealed that these institutions are just as affected by the changing conservationist landscape as in situ initiatives, and that many collecting and captive breeding projects are reorienting themselves to participate in proposals which I designate collectively as *transformative conservation*. Zoos, botanical gardens, seed banks and gene banks are not simply or not only storing genetic information or suspending life; the captive endangered populations they foster are always already in circulation, involved in various breeding and experimental projects, constantly being regerminated or hybridised, rather than preserved in an enclosed space designed to skip the coming environmental apocalypse. The case for studying the contradictions between ex situ conservation and fluidly recombinant ecosystems has become weaker, if not entirely outdated, and analysing the ontological politics of the rich and varied transactions taking place ex situ has emerged as the more pressing question to ask.

The working definition of transformative conservation used throughout this thesis is a set of practices that treat the species or individuals they wish to protect in ways that foster their emergence as plastic subjects endowed with a certain

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[2] See for instance Chris D. Thomas, "Rapid Acceleration of Plant Speciation during the Anthropocene", Trends in Ecology & Evolution 30, no. 8 (August 2015): 448–55; Richard J. Hobbs, Eric S. Higgs, and Carol M. Hall, eds., *Novel Ecosystems: Intervening in the New Ecological World Order* (Chichester: Wiley-Blackwell, 2013); Emma Marris, *Rambunctious Garden: Saving Nature in a Post-Wild World* (New York: Bloomsbury, 2011); Fred Pearce, *The New Wild: Why Invasive Species Will Be Nature's Salvation* (London: Icon Books, 2015).

amount of individual and inter-individual agency. These projects are connected to a suite of conservation practices that include rewilding, de-extinction, cloning, novel ecosystems management or urban ecologies – in short, a range of proposals that could classified as "post-normal", or "conservation after nature", less concerned with essences than with processes, and indicative of a new conservation epistemology predicated on relational ontologies and immanent ecological assemblages.[3] The marginal and often controversial conservation proposals I examine in this thesis – assisted migration, crop wild relative conservation, and assisted evolution – seek to transform or to utilise that which they purport to save, and to enrol the unpredictability of the geographical, genealogical and temporal processes characterising these species in order to securitise different aspects of their futures. I propose to read these practices both as power formations enabling biopolitical interventions and as forms of quasi- or proto-cosmological negotiation. This framework usefully avoids flattening these practices into uniformity and treating them merely as varied but essentially similar avatars of a hypertrophied modernity, an extension of human agency and dominion over nonhuman nature, or of developing dreams of mastery over the stuff of life itself. Examining transformative conservation practices as sites of rehearsal and not only as the expression of a unified governmental rationality allows for them to be granulated more finely, and allows one to see more clearly the potential negotiations and contestations in which conservationists are engaging.

This thesis therefore aims to critically investigate what instances of transformative conservation reveal about the wider turn of conservation biology to "postnormal", relational, or neoliberal understandings of nature; to trace the resurgence of conservationist pasts in contemporary practices and how transformative conservation mobilises expertise and concerns inherited from colonial botany, agriculture, and horticulture, as well as deeper co-evolutionary histories; and, finally, to tease out the speculative potential of these transformative proposals in order to examine the

[3] See for instance Katja Grötzner Neves, *Postnormal Conservation. Botanic Gardens and the Reordering of Biodiversity Governance* (Albany: State University of New York Press, 2019) and Jamie Lorimer, *Wildlife in the Anthropocene. Conservation after Nature* (Minneapolis: University of Minnesota Press, 2015).

oppositional politics they might enable, and how these translate into experimental world- and future-making.

Chapter 1 recapitulates the history of conservation biology, and the tensions produced by various attempts at defining and justifying its objects, aims, and methods, laying the groundwork for my approach toward transformative conservation proposals as experimental bio- and cosmopolitical interventions. This chapter traces the emergence of conservation biology as a "crisis science" in the 1970s and 80s and discusses its rootedness in colonial botany, horticultural practices, and agricultural concerns. It then touches on the various debates that have led to the definition, distribution, and interaction of in and ex situ conservation initiatives, and lays out how recent developments in molecular biology and cryotechnologies are modifying ex situ conservation. The increased laboratisation of the institutions conducting ex situ conservation projects has created a space for experimental practices in which the unpredictability and recalcitrance of wild plants and animals can be put to speculative use at the very same time scientists are attempting to tame and control them. This, I argue, is the space in which transformative proposals become thinkable and testable, and it is in their experimental reconfigurations of biosocial relations that ex situ institutions must be read as sites where resistance and oppositional politics (in addition to operations that are complicit with hegemonic forms of power) can be assembled and articulated.

Chapter 2 focuses on assisted migration, the deliberate translocation of species threatened by climate change to ranges where they would be predicted to move were it not for temporal constraints or anthropogenic dispersal barriers. Assisted migration serves as a first exploration of the epistemological and ontological shifts that have reconfigured conservation biology since its formal consolidation into a discipline – shifts that are not legible if conservation biology is approached with the assumption that it is still largely based on static and essentialist ontologies. On the basis of a Foucauldian analysis of governmentality and security, I argue that assisted migration both drives and feeds on a turn to ontological indeterminacy, incalculable contingency, and a neoliberal form of governmentality whose object is circulation and the regulation thereof. I argue that this shift is particularly legible in the distortions a proposal such as assisted migration imposes on the meaning, use, and function of ex situ seed collections, forcing scientists to re-evaluate how they understand and constitute available stores of species held and bred in captivity. This is particularly salient in the literature discussing whether existing plant collections are suited at all to restoration and translocation projects, and whether implementing them would require a complete overhaul of collection practices in order to constitute genetically diverse and robust accessions. Stockpiling becomes involved in the securing rather than the suspension of circulation, and fully integrates the possibility of a neoliberal "governance through disorder".[4]

I then sketch out how assisted migration sits at the confluence of a new understanding of nature as radically fluid and unpredictable and of a reactivated expertise in plant breeding and translocation accumulated in the botanic garden horticulture and plantation ecologies that have shaped Euro-centric modernity. This context is what makes assisted migration such a potent locus for imagining frictionless, scalable processes of intervention into nonhuman movement and distribution, and I examine how these proposals for wildlife management fall in line with fantasies of escaping degraded terrestrial conditions and adapting terraforming practices to conservation biology. I end by switching to a more anthropologically informed framework, which allows me to shed light on another speculative trajectory present in assisted migration. But the dreams of scalability are not as self-evident as part of the literature on the topic would suggest. Warnings about the nonreplicable specificity of each species and individual that migrates, combined with an emerging reliance on narratives about intertwined deep histories of human and nonhuman dispersal and migration, form an oppositional undercurrent in the literature that I propose to analyse as another speculative opening, this time pointing toward a greater reliance on historical path-dependency and a refusal to naturalise a disorder that would serve neoliberal governance.

Chapter 3 focuses on the conservation of crop wild relatives. While the practice of conserving wild taxa related to our domesticated crops and interbreeding them with the latter in order to transfer useful traits such as resistance to drought, pests and salinity has been ongoing in the agricultural gene banks of the Consortium of International Agricultural Research Centers, the project I propose to examine here is novel in scope and in location. Named Adapting Agriculture to Climate Change: Collecting, Protecting and

[4] See Luigi Pellizzoni, "Governing through Disorder: Neoliberal Environmental Governance and Social Theory", *Global Environmental Change* 21, no. 3 (August 2011): 795–803.

Preparing Crop Wild Relatives (or the Crop Wild Relatives Project for short), it has been underway at the Millennium Seed Bank of the Royal Botanical Garden, Kew since 2011. The novelty of this project lies both in the large scale of its target (29 priority crops), and in the fact that it fully realises the potential of botanical gardens to serve agricultural concerns. This convergence has been propelled by the publication of several surveys over the last two decades pointing out both the usefulness and the patchiness of crop wild relative accessions in botanical gardens, and calling for a better integration of these fragmented collections.

In this chapter, I examine how the scientists involved in crop wild relative conservation bring together two different *dispositifs* (agricultural and conservationist), and thus constitute wild and domesticated species as differently endangered and simultaneously robust: crops are vulnerable because too well adapted to industrialised societies, crop wild relatives because they are too little; crops are resilient because managed in the violent care of human supervision, and crop wild relatives because they have been able to test their mettle against a variety of nonhuman foes undisturbed. This transforms survival into a matter of relationality, of synchronising rhythms and genealogies across different categories of species, and of retrieving abilities from differently vulnerable relatives. Rather than focusing on the projected transformation and enhancement of agricultural crops, I go on to analyse how this project subjectifies wild species, recasting them as creative and resilient in ways that have developed alongside and separate from human ingeniousness. This development is indebted to a neoliberal conceptualisation of the entrepreneurial self, and its role in enabling transformative conservation to co-opt nonhuman creative processes must be examined critically. I end with an analysis of how this co-opting of a paradoxically valued remnant of irreducible wildness fits into the wider *longue durée* history of domestication since the Neolithic Revolution. I ask whether the discursive reliance on this Neolithic history in the literature about crop wild relatives is indicative of an extension of domestication and of a (re)colonisation of interspecies processes previously exempt from it, and whether the Crop Wild Relatives Project could not be read against the grain as a diplomatic intervention opening up the possibility of resisting the very logic and ethics inherited from Neolithic relations. In its enrolment of and negotiations with wild species, the conservation of crop wild relatives can be read as an example of interspecies diplomacy that reactivates alternative histories with unsuspected and unplanned-for subversive effects.

Finally, Chapter 4 examines the issue of assisted evolution, the selective captive breeding of endangered wild species with the goal of making them more resistant to a variety of threats; it focuses in particular on the assisted evolution of several coral species, a research project currently underway at the Australian Institute of Marine Science. While assisted evolution has also been conducted on a small scale on amphibians, most notably the Panamanian golden frog, the proposal has been taken up most extensively and robustly in coral conservation. The AIMS is currently involved in two projects, the first conducting intraspecies breeding and the second focused on the hybridisation of different subspecies, with the aim of selecting for corals that will be more resistant to the rising temperature and increasing acidification of the oceans they inhabit.

This chapter traces the emergence of genetic rescue as a scientific and conservationist issue, and how the possibility of revitalising populations threatened by genetic bottleneck has gradually shaded into proposals to selectively breed resistant individuals. The coral assisted evolution projects carried out at the AIMS fit into the general redistribution of laboratory and field practices brought about by transformative conservation. Here I apply Isabelle Stengers' distinction between field sciences, experimental science and technological innovation, in order to trace how assisted evolution laboratises the wild and subordinates the laboratory to practices more in line with engineering than experimental sciences. This renders corals as potential model organisms and risks reducing them to a set of abstract, manipulable processes and genetic markers.

I argue, however, that the very openness of these experiments, their continued dependence on the contingencies of the field, where every assumption and proposal will be tested again and again by and in the endangered beings themselves without the possibility to fully stabilise the outcome of the experiment, complicates a reading that would place it firmly on the side of bio- and geoengineering projects. In its cleaving to irreducible field conditions and the agency of hybridising corals, it involves itself in a shifting ecology of practices and ontological politics: its transformative practice questions categories and taxonomies previously established in conservation biology. The coral scientists of the AIMS are engaged in forms of strategic exclusion and distancing, but the reductionist space of the laboratory also allows for the emergence of corals as a set of complex, interwoven and evolving capabilities that far exceed genetic essentialism. In assisted evolution projects, peculiar abilities of these species – a combination of different types of evolutionary processes and reproductive modes, borrowing from both vegetal and animal strategies – emerge as newly useful. While assisted evolution is embedded in technoscientific projects of progress and enhancement, it is also engaged in remobilising the temporal agency or animacy of corals and counteracting forms of colonial and capitalist artefactualisation of nature. What is animated in this project is a denaturalised figure of corals and coral reefs, which are now understood as engaging in continuous and complex forms of interspecies labour. Assisted evolution opens up the possibility of surviving not extinction itself but the destruction of constructed kinship ties that would make recovery after mass extinction events difficult.

By examining these three different but interlinked instances of transformative conservation, I aim to bring attention to the variety of what Viveiros de Castro calls "different Earths" that is produced in and through conservation projects.[5] Each of these projects intervenes into nonhuman lives, bodies and compositions differently, and in so doing they rehearse various version of planetary futures, calling on cosmologies that largely exceed the spaces in which these interventions take place.

[5] Eduardo Viveiros de Castro, "On Models and Examples: Engineers and Bricoleurs in the Anthropocene", *Current Anthropology* 60, no. S20 (August 2019): S296–308, S298.

Chapter 1.
"A crisis discipline": The Shifting Topologies of Conservation Biology

This introductory chapter, structured in two parts, provides an overview of the field in which I have unfolded my inquiries and the scholarship these inquiries respond to, draw on, and contribute to. First, I will provide a historical account of the emergence of conservation biology as a discipline, jumping in at the moment of its reckoning with postmodern scholarship before going back to its inception as a "crisis science" and highlighting the experimental and pragmatic nature of the practices making up the field. I will then shift to a brief history of ex situ conservation, which has provided the context in which my inquiry unfolds. I show how the turn of zoos and botanic gardens toward conservation activities has contributed to the emergence of liminal, experimental conservationist spaces, recalling a few historical elements necessary to understand the emergence of these institutions and their place in dense networks of extraction and circulation.

In the second part of this chapter, I will tie this multi-layered historical excursus into the methodological considerations that will guide the analysis of my case studies. Rather than conducting an excavation of hidden agendas and unconscious biases in conservation biology, I aim to recontextualise the spaces and practices investigated here in order to highlight their speculative breadth and richness. I contend with recent critical scholarship about the technologies buttressing the long-term, suspensive conservation of living and banked collections, noting that it must be complemented with sustained documentary research into the technological issues and practical aims of ex situ conservation if we are to adequately capture the experimental nature of the field. This manifests in the case studies examined later, which emerge in and around the experimental plots and laboratorised apparatuses of captive-breeding institutions. I will sketch out the methodology that has guided my research, and an overview of the theoretical structure that will be unfolded in more detail across the next three chapters.

I. Background: The Birth of a Heterogeneous Discipline

1. Strategic Positioning

> The need for such a redirected conversation is made even more obvious by the fact that all too often barriers akin to cultural boundaries have been erected between humanistic emphasis on the role of human conception in establishing what is "natural" and scientific insistence on nature as "given." Major aspects of these "two-culture" problems with respect to "nature/ecology/wilderness" have rarely if ever been exposed to multidisciplinary dialogue; as a result, many confusing issues and semantic debates continue to hamper the discovery of the basic issues. We saw earlier, for example, that construction of nature, espoused so pointedly by Haraway, can be interpreted in at least two ways: one is the cultural *context* in which nature is understood; the other involves the actual *content* and *structure* of that nature.

— Lease, 'Introduction: Nature Under Fire', in Lease and Soulé, *Reinventing Nature? Responses to Postmodern Deconstruction.*

These lines are quoted from the introduction to a combative volume co-edited in 1995 by Michael Soulé, one of the founding figures of conservation biology, and Gary Lease, at the time professor of history of consciousness at the University of Santa Cruz. The book itself is an interesting regional artefact of a wider debate – the "Science Wars" waged between scientific realists and constructivists – that marked the 1990s, and stands as an example of the often complicated dialogue between conservation biology, merely a decade old at the time, and a subset of the humanities designated by the Lease and Soulé as "postmodern deconstruction." Published as a response to a three-year research project under way at University of California, Irvine at the time and called "Reinventing Nature" (minus the question mark added by Lease and Soulé), this volume emerged from a conference specifically organised to fill in a perceived gap in "dialogue between the worlds of the natural sciences and the humanities"[1] and responding to a period of

[1] Gary Lease, "Introduction: Nature Under Fire," in *Reinventing Nature? Responses to Postmodern Deconstruction*, ed. Gary Lease and Michael E. Soulé (Washington, Covelo, London: Island Press, 1995), 7.

humanist effervescence when it came to rethinking nature, environmental change, and ecological practices.

Reinventing Nature? is characteristic of a conceptual enclosure that has shadowed the birth of conservation biology itself – an emergence attended by considerable anxieties regarding the definition of just what conservation biology *was*, which objects it would claim as its own, and what its scope would or could be. Born in a context of chaos and crisis and cobbled together from a wide range of disciplines, conservation biology seems, in its beginnings, to have been at particular pains to give itself a political and scientific status resting on a non-ambiguous definition of nature or biodiversity. If conservation biology was to find wide acceptance in the form of funding and influence on future policies – in Latourian terms, if it was to interest potential allies[2] – it had to justify its interventions by anchoring itself in solid ground. The sentiment expressed in the preface of *Reinventing Nature?* and taken up by some of its contributors is confused, if not disingenuous. While his call for multidisciplinary exposure is more than justified, Lease sets up a dichotomy between perceptions and conceptions of nature (asking whether possible cultural differences in perception would have implications for environmental policy) on one hand, and the empirically verifiable effects of human activity on nature through various husbandry technologies on the other. This rhetorical split between context and structure, the productive mechanisms of discourse and the results of that production, the making of knowledge and the exertion of power, allows him to ask overly simplistic questions. Chief among them is the perceived need to differentiate clearly between the conceptual invention of nature as a cultural construct and the permission to engage in the unbridled invention of new biophysical entities, a bogeyman insistently haunting the introduction to this volume. Strategically misunderstanding what a crudely defined poststructuralist thought might bring to conservation discourse means that any attempt to critique conservationist principles can be construed as complicit in the "physical assault" currently weathered by a nature under siege.[3] It is not only that the volume does not distinguish finely between the various schools of thought and types of methods that have been mobilised in critiques of conservation biology, and does not

[2] See Bruno Latour, *Science in Action. How to Follow Scientists and Engineers through Society* (Cambridge, Massachusetts: Harvard University Press, 1987), 173–76, on the double figure of the *enlisting* scientist and the *enlisted* employee, whose work is marked by enormous exertions to place their project within those of other actors, and thus form aligned interest groups.

[3] Lease and Soulé, *Reinventing Nature?,* 137.

adequately address differences between feminist scholarship, critiques of the wilderness concept, postcolonial analyses, and other approaches. Significantly, it also treats deconstruction (or poststructuralism, or social constructivism) as an "ideological" threat parallel to the material assault against nature. Framing it as such allows Soulé, for instance, to simultaneously decry "conservative free market capitalists, humanists concerned with the emancipation and empowerment of certain social and ethnic groups, and others, including animal rights organizations" as partners in a covert relativist strategy.[4]

This discourse, then, seem to have been at least partly informed by the need to secure the position of a discipline in the making, and to salvage the political importance of protecting endangered species and ecosystems. This reaction would, decades later and at the time of writing this dissertation, find a certain degree of justification in the rise of "post-truth politics" – a development that also proved to be somewhat of a reckoning for a number of scholars once involved in the Science Wars, or, in Isabelle Stengers' words, "the dreadful historical irony that social constructivism may be described as unwittingly collaborating in the destruction of those very aspects of science that it derided."[5] While *Reinventing Nature?* enacts what might be viewed as a kind of "strategic essentialism" in order to shore up a stable concept of nature,[6] earlier foundational texts of conservation biology are explicit about the integration of "ecophilosophy" into conservation biology. Michael Soulé's 1985 article "What is Conservation Biology?", which will stand in here as the best-known and -publicised example of this literature, does not shy away from stating that "[t]olerating uncertainty is often necessary" in the disturbed context conservation biology operates in, and that:

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[4] Lease and Soulé, *Reinventing Nature?,* 146.

[5] Isabelle Stengers, "Deleuze and Guattari's Last Enigmatic Message," *Angelaki* 10, no. 2 (August 2005): 151–67, 155. This question has also been reprised by Latour in his 2018 book *Down To Earth*, in which he approaches climate denialism as an issue that must be faced not with a reinvigorated heroic narrative of pure science opposing political stupidity, but with a renewed attention to how scientific facts are constructed and communicated.

[6] Using the term introduced by Gayatri Chakravorty Spivak in *In Other Worlds* here might steer away too much from its original definition as a subaltern strategy; while the discipline might be a minor one, its practitioners were and still are most often selected from decidedly dominant categories. They were, however, engaged at the time in a strategy of speaking *on behalf* of nonhuman others who at the time may not have been defined as subaltern, but are so now by scholars extending Spivak's critique to more wide-ranging analyses of anthropocentrism (on this shift, see Rohan Deb Roy, "Introduction: Nonhuman Empires," *Comparative Studies of South Asia, Africa and the Middle East* 35, no. 1 (1 May 2015): 66–75.)

> virtually all conservation programs will need to be buttressed artificially [...] poaching, habitat fragmentation, and the influx of feral animals and exotic plants require extraordinary practices such as culling, eradication, wildlife immunization, habitat protection, and artificial transfers.[7]

Conservation biologists, we see, are not intrinsically or originally squeamish about discussing the interventions necessitated by their practices, and naming the transactions that blur the differences between what is given and what is constructed. It seems to me that the best diagnosis of what is at stake in this particular conflict is that the humanities have caught a particularly ticklish field right before it could stabilise (albeit only into a temporary and relative form). If we follow the distinction between *science in the making* and *ready made science* drawn by Latour in *Science in Action*, the picture painted by Soulé's "status report" in *Reinventing Nature?* is that of a scientist forced by a perceived derision of the "warm," unstable side of his field to speak prematurely with the bearded mouth of the cold face of Janus.[8] Conservation biology, now as much as forty years ago, is engaged in the open, risky production of facts and practices. It might, in fact, be constitutionally unable to reach the cold, authoritative state of ready made science, because if it is a science at all it is a crisis one, shot through with the innumerable lines of flight inherent to its unstable and threatened context and objects.

This is why the strategically reactionary movement that followed the perceived "postmodern" encroachment on conservationist terrain – and which resulted in acts of ventriloquy such as the one I have just mentioned – are not always the best starting point of an inquiry into this discipline and the natures it produces. Doing so would lead either to rehashing a debate centred on a mode of deconstruction that has already been multiply refined since then,[9] or accepting a reduced version of conservationist politics along with taking this defensive essentialism at face value. This point is echoed in a diagnosis made by William Chaloupka and R. McGreggor Cawley, writing about wilderness politics during the height of this debate, when they state that:

> if there has been an interesting oppositional politics around the politics of wilderness – and it seems to us that this has been the case, at least intermittently – it may be that this politics makes more sense if taken out of

[7] Michael E. Soulé, "What Is Conservation Biology?", *BioScience* 35, no. 11 (1985): 9, 729.
[8] Latour, *Science in Action*, 4.
[9] Latour's *Pandora's Hope*, for instance, is a book-length response to the dagger-drawing of the Science Wars and represented one of many attempts to rescue science studies from the mistakes of modernist anti-fetishism.

> the romantic or Utopian mode. In other words, wilderness activists may have been doing something different from what they say (and think) they are doing. In fact, some of environmentalism's best actions have been heterotopic, self-consciously creating juxtapositions and alternate loci for withdrawal and opposition.[10]

My objective in mentioning a debate which this thesis will in large part circumvent is to illustrate the fact that the discipline I am investigating here has always been, even before its formal inception, involved in forms of "oppositional politics," speculative and generative interventions that strategically mobilise seemingly essentialist definitions. This tendency has been present in all the developments leading to its contemporary incarnations, and has been variously hushed or made explicit at different moments of conservationist history. The present moment, marked by the rise of what I propose to call *transformative conservation*, is particularly rich in resurgences of this oppositional discourse, as the jumbled components of the discipline are being rearranged in a context of crisis and of uncontained ecological and ontological proliferations.

My aim in contending with contemporary shifts in conservation biology is not to provide a reading that might call forth a response from conservationists that would merely repeat the move already played out between Reinventing Nature the conference and *Reinventing Nature?* the volume. It is, rather, to "resist the image of science as a simple case of social construction" without eschewing an investigation into the effective, generative politics of the field.[11] While I am not heeding the warning formulated by Stengers when she experiments with Deleuze and Guattari's last injunction for philosophers not to intervene into science in the making, I am aware that it has been issued.[12] However, the fact that conservation biology might be constitutionally unable to

[10] William Chaloupka and R. McGreggor Cawley, "The Great Wild Hope: Nature, Environmentalism, and the Open Secret," in *In the Nature of Things. Language, Politics, and the Environment*, ed. William Chaloupka and Jane Bennett (Minneapolis: University of Minnesota Press, 1993), 13.

[11] Stengers, "Deleuze and Guattari's Last Enigmatic Message," 155.

[12] "But we are also poisoned, lacking resistance to the present, when in all sincerity we denounce the bearded dreams of science, forgetting to create the means to resist being joined by others who have undertaken to destroy the dreamer. Resistance is a matter of creation, not of sincerity. Deleuze and Guattari were not 'sincere' when celebrating mature science; they did not participate in a sincere, consensual belief in the 'autonomy of science.' Celebrating mature science as creation, they endeavoured to create means – philosophical means – to tell another story, to escape the consensual opposition between the claims of a bearded science and the critical deconstruction of these claims. This is the process of creation I now wish to continue." (Stengers, "Deleuze and Guattari's Last Enigmatic Message," 155).

achieve a cold, stabilised form of any kind means that one can *only* engage with its crisis topologies at the constantly renewed moment of their making; and also that there is no royal, dogmatic science to oppose, contradict or undo, only a set of practices to follow, experimental knots to witness, and negotiations to foreground.

2. The Emergence of a Crisis Science

Before leading into the (re)emergence of transformative conservation projects, let me sketch out the context in which conservation biology first appeared as a named discipline. The seeds for the birth of conservation biology, a "synthetic, eclectic, multidisciplinary structure," were sown at a banquet held in 1978 at the San Diego Wild Animal Park.[13] This meeting was comprised of "an odd assortment of academics, zoo-keepers, and wildlife conservationists," as Ann Gibbons describes what would later come to be known as the First International Conference on Conservation Biology.[14] Among other things, this meeting led to the publication in 1980 of a landmark book, *Conservation Biology: An Evolutionary-Ecological Perspective*. The formal consolidation of conservation biology a few years later can be dated almost to the hour, namely the closing of the Second Conference on Conservation Biology around 5 pm on the 8th of May 1985, when "[a]n informal motion to organize such a society [Society for Conservation Biology] was approved by acclamation."[15] The society started to publish its own journal, *Conservation Biology*, in 1987, and a first textbook, *Research Priorities in Conservation Biology*, followed in 1989. While this is the official history recounted in most histories of the discipline written in the past decades, it is worth noting that by the time the Society for Conservation Biology came into being, the European journal, *Biological Conservation*, had existed for almost two decades.[16]

Conservation biology the discipline was, at the time, coming together against a complex background composed of various scientific and ethical elements. J. Baird Callicott, for instance, identifies three different strands in the "moral foundations of American Conservation." The first is the "romantic-transcendental preservation ethic,"

[13] Fred Van Dyke, *Conservation Biology: Foundations, Concepts, Applications* (Dordrecht: Springer Netherlands, 2008), 3.
[14] Ann Gibbons, "Conservation Biology in the Fast Lane," *Science* 255, no. 5040 (1992): 20–22, 20.
[15] Michael E Soulé, "History of the Society for Conservation Biology: How and Why We Got Here," *Conservation Biology* 1, no. 1 (1987): 4–5, 4.
[16] It was created in 1968 and is now affiliated with the Society for Conservation Biology.

formulated by Emerson, Thoreau and Muir, which cast nature as a temple and wilderness as the locus of salvation for the world. The second is a "resource conservation ethic" championed by Pinchot, concerned with a fair and utilitarian distribution and management of nature seen as resource. Callicott calls them, respectively, preservationists and conservationists, and notes that both ethics are ultimately anthropocentric in that they "regar[d] human beings or human interests as the only legitimate ends and nonhuman natural entities and nature as a whole as means." It is Leopold's land ethic, he suggests, that truly brought together elements of both stances together in an "evolutionary-ecological paradigm" informed by new ecological findings that highlighted the interconnectedness of biotic systems as well as human dependence on nature as more than a reservoir of resources or experiences. According to Callicott,

> The public agencies are still very much ruled by the turn-of-the-century Resource Conservation Ethic; some of the most powerful and influential private conservation organizations remain firmly rooted in the even older Romantic-Transcendental philosophy; while contemporary conservation biology is clearly inspired and governed by the Evolutionary-Ecological Land Ethic.[17]

Writing in 1990, at a time when conservation biology was still finding its ethical legs, Callicott concludes with the hope that conservation biology will fully embrace a land ethic that does not exclude humans and industrial activities from nature, and "no longer […] say, simply, that what existed before the agricultural-industrial variety of *Homo sapiens* evolved or arrived, as the case may be, is the ecological norm in comparison with which all anthropogenic modifications are degradations."[18]

By the time Callicott published this article, Soulé had already authored one of the seminal definitions of the principles structuring this fledgling discipline, focusing on *biodiversity* as the object that conservation biology uneasily decided to settle on. Conservation biology, according to him, is distinguished from other biological disciplines by its crisis context; this context conditions the necessity for conservation biology to borrow from a wide range of disciplines, while also blurring the distinction between pure and applied sciences. It is holistic and focused on long-term viability. Soulé goes on to list functional postulates: "many of the species that constitute natural communities are the

[17] J. Baird Callicott, "Whither Conservation Ethics?," *Conservation Biology* 4, no. 1 (1990): 15–20, 18.
[18] Callicott, "Whither Conservation Ethics?," 19.

products of coevolutionary processes"; "many, if not all, ecological processes have thresholds below and above which they become discontinuous, chaotic, or suspended"; "genetic and demographic processes have thresholds below which nonadaptive, random forces begin to prevail over adaptive, deterministic forces within populations"; and "nature reserves are inherently disequilibrial for large, rare organisms."[19] These are complemented with normative ones ("diversity of organisms is good"; "ecological complexity is good"; "evolution is good"; and "biotic diversity has intrinsic value"[20]), which according to him form an "ecosophy" (in the Naessian sense of the term rather that the Guattarian) that also resonates with the Leopoldian evolutionary-ecological paradigm Callicott would later call for.[21] Soulé is at great pains to distinguish anthropogenically conditioned extinction events from what he calls "natural extinction," and to explain that conservation biology is not concerned with animal welfare or individuals but populations. "Species," he concludes in one of the many generalising and abstracting moves that characterise this article, "have value in themselves, a value neither conferred nor revocable, but springing from a species' long evolutionary heritage and potential or even from the mere fact of its existence."[22]

This article cemented conservation biology's specific status as a value-laden, goal-oriented discipline working with uncertainty and urgency, and based on intrinsic rather than instrumental values; conservation biology is not so much concerned with establishing theories as it is with first-response practices answering situated ecological urgencies. As such, it is experimental in the technological sense more than the laboratory-scientific one, collapsing distinctions between technology and science and laboratory and field in ways that will be attended to in the next chapters.

But attending to the transformative effects of conservation paradigms and practices on scientific landscapes means that it is difficult to start, as philosophers such as Callicott and conservationists such as Soulé do, from the ethical end of things. Any

[19] Soulé, "What Is Conservation Biology?," 729–30.
[20] Soulé, "What Is Conservation Biology?," 731.
[21] On these two diverging ecosophies, see Arne Naess, *Ecology, Community and Lifestyle: Outline of an Ecosophy*, trans. David Rothenberg (Cambridge: Cambridge University Press, 1990) and Félix Guattari, *The Three Ecologies*, trans. Ian Pindar and Paul Sutton (London: The Athlone Press, 2000). Naess defines the term as any articulated philosophy of natural equilibrium; Guattari, on the other hand, uses the term to describe a study of the complex interactions between mental, social and environmental ecologies. The postulates listed in Soulé's article are engaged in formulating the former rather than practising the latter.
[22] Soulé, "What Is Conservation Biology?," 731.

attempt, from within conservation biology, to write an ethical manifesto for the discipline must necessarily imply the imposition of one partial voice as representative of an eclectic field. And a biocentric ethics such as the one proposed by Soulé in 1985 does not permit inquiry into just what a species, or evolution, *is*; or rather about how these objects are made, articulated, transformed by conservation practices themselves. The difficulty here is that these practices do not compose a monolithic, homogeneous field, and that attempting to read a topology of multiple, often unreconciled proposals through a single lens, is both reductive and hasty.[23] To state that conservation biology is "clearly inspired and governed" by any unambiguously identifiable ethics is to foreclose an ecological attention to the "local, material, mundane sites where the sciences are practiced,"[24] and where conservation biology is constantly remaking and renegotiating its own varied and conflicting ethical stances. As a quick overview of recent conservationist debates will show, the ethical question of just what forms relations between humans and nonhumans should take is far from settled within the discipline itself. And thus, while we might very well come upon ethical frameworks again later on, we must begin "through the milieu,"[25] where scientists of various trainings and persuasions act as diplomats and experimenters in a catastrophically shifting habitat, and examine the objects, agencies, and ethics they produce through these crisis practices. Conservation biology must be repopulated "as a proliferative space of difference,"[26] as a way of resisting the under-problematised power of normative ethical statements.

3. Ex Situ Practices

Thinking conservation biology and the shifts in its recent topology in this way – through the middle or the *milieu* – takes the form, in this inquiry, of an engagement with a densely problematic conservationist subfield: ex situ conservation. Opening this particular fold of conservation biology means paying attention to fragmentations and

[23] On positionality, see Donna Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016), 41.
[24] Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, Massachusetts: Harvard University Press, 1999), 309.
[25] Gilles Deleuze and Félix Guattari, *A Thousand Plateaus. Capitalism and Schizophrenia*, trans. Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 9–10.
[26] J.K. Gibson-Graham, "Diverse Economies: Performative Practices for 'Other Worlds,'" *Progress in Human Geography* 32, no. 5 (October 2008): 613–32, 615.

negotiations that depart from the debates surrounding general attempts at defining conservation biology. Starting with a contested fracture in conservation practices is a double-pronged move. The debates around ex situ conservation highlight the usefulness of a geographic approach to conservation biology, where the embodied transactions and productions taking place are dependent on variously localised practices. This, in turn, opens up the possibility of understanding the wider operations (not only the spatial distributions) of conservation biology topologically, enriching previous engagement with ex situ practices with an attention to "hybridised" geographies connecting conservation practices across the spaces in which they are enacted.[27]

Ex situ, in situ, inter situ: the vast body of conservation biology practices is animated and agitated by questions of place – of circulating lives and matter, in place or out of place, of ecosystemic and existential fragilities desperately hammered into the shifting sands of changing landscapes or reshuffled in the hope that they might yet live and be remembered, even in another place, even in another time. Place, or placement, is what provides the most prominent and apparently obvious lines along which conservation biology structures itself, and place is also the contentious friction point sparking some of the questions I propose to unfold here. The topologies of conservation biology are not coincidental or insignificant, and they are always also signifiers of something other than mere bodily spatiality; as Sarah Whatmore reminds us, our understanding of the distributions of nature and society, or wildness and domesticity, are always ordered by "moral geographies."[28]

While early articulations of conservation biology were ostensibly concerned with *what* exactly was to be its object – what or who was to be paid heed to, nurtured, protected and defended – one useful entry point into how conservation practices create this object is tracing how they have asked *where* biodiversity was to be protected. The experimental soil in which conservation biology is rooted is already one pre-divided into enclosed spaces: island biogeography has functioned as an important simulator for conservationist approaches to reserve design. Richard Grove has provided a detailed historical account of how islands simultaneously became sites of extraction fuelling the expansion of European empires and reservoirs for Utopian or Edenic imaginaries

[27] See Sarah Whatmore, *Hybrid Geographies: Natures Cultures Spaces* (London: SAGE, 2002).
[28] Whatmore, *Hybrid Geographies,* 9.

between the sixteenth and nineteenth centuries.[29] But this was not the end of their evolving presence in Western science and ecological discourse. As the ecologist Daniel Simberloff has noted, "oceanic islands are paradigms," and many influential evolutionary and biogeographical advances "rest originally on insular observations," including Darwin's and Wallace's seminal contributions to the concepts of evolution and natural selection.[30]

Island biogeography, in particular, was to have a "paradigmatic influence"[31] on conservation biology. Formulated in 1967 with the goal of developing a general theory of species distribution and its dynamics, Edward O. Wilson's and Robert A. MacArthur's equilibrium model revolutionised the field of ecology and evolution. They postulated that species richness on islands had a stable equilibrium (in which immigration and extinction rate are balanced so as to preserve species richness in spite of a constant turnover), and that distance from the mainland determines the immigration rate and island size the extinction rate – in short, species diversity is contingent on island size and its level of isolation.[32] They devised a mathematical model able to predict the equilibrial species number on a given island; it was tested in 1969, when Wilson and Simberloff devised opportunistic "field experiments"[33] in mangrove defaunation, in which they monitored the return of terrestrial arthropods after fumigation to six small islands in Florida Bay.[34]

The equilibrium model proved not only influential in consolidating a chaotic field made up of reticulated genealogies, but also foundational for the practical implementation of conservation programs. Islands emerged as useful reduced models to study, but also a prophetic warning against the future shaping of existing biomes by anthropogenic pressure: as MacArthur and Wilson put it, "the same principles apply, and will apply to an accelerating extent in the future, to formerly continuous natural habitats now being broken up by the encroachment of civilization."[35] This idea was taken up most

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[29] See Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism, 1600-1860* (Cambridge: Cambridge University Press, 1995).

[30] Daniel Simberloff, "Equilibrium Theory of Island Biogeography and Ecology," *Annual Review of Ecology and Systematics* 5, no. 1 (November 1974): 161–82, 161.

[31] Mark V. Lomolino and James Brown, "The Reticulating Phylogeny of Island Biogeography Theory," *The Quarterly Review of Biology* 84, no. 4 (December 2009): 357–90, 358.

[32] See Robert H. MacArthur and Edward O. Wilson, *The Theory of Island Biogeography* (Princeton: Princeton University Press, 1967).

[33] Lomolino and Brown, "The Reticulating Phylogeny," 377.

[34] See Edward O. Wilson and Daniel S. Simberloff, "Experimental Zoogeography of Islands: Defaunation and Monitoring Techniques," *Ecology* 50, no. 2 (March 1969): 267–78.

[35] MacArthur and Wilson, *The Theory of Island Biogeography,* 4.

prominently by Jared Diamond, who argued that protected areas should be assessed with a view to their insular characteristics, and that setting aside small tracts of land to protect might do more harm than good in the long run.[36] His intervention was one of the element that spawned a vitriolic debate around "SLOSS" ("single large or several small") conservation areas in the conservation community. It was largely resolved in favour of single, large protected areas and later recast as a matter of connectivity: the issue is not only that existing reserves are too small, but that they lack a solid enough network of green corridors allowing for the migrations that are so vital for maintaining equilibrium. Spaces, borders, boundaries, and selected pathways of circulation have perhaps been the object *par excellence* of conservation biology for the last fifty years. These geographies (and geopolitics) are leaky, contested, and created at the intersection of human and nonhuman agencies, and "borders and border crossings feed back to conservation theory and practice," as Valdivia, Wolford, and Lu show in their study of reserve border crossing and rearticulated conservation practices in the Galápagos Islands.[37]

But natural reserves have not been the only places where conservation biology is enacted, and certainly not the only contentious ones. While conservationists were debating, contesting, redrawing and connecting the borders of natural reserves, many of them were also engaging in re-evaluating the past and future role of institutions holding endangered species in captivity. The history of conservation biology is marked by the progressive integration of problematic institutions such as zoological and botanical gardens into conservationist agendas. While these institutions have been fairly successful in reinventing themselves as conservation nodes, at least in their public self-portrayal, this development has been far from self-evident, requiring the strategic deployment of guidelines, treaties, acts and public statements.[38] Their shift to fulfilling ex situ conservation duties – made possible by the infrastructural preparedness of institutions

[36] See Jared M. Diamond, "Biogeographic Kinetics: Estimation of Relaxation Times for Avifaunas of Southwest Pacific Islands," *Proceedings of the National Academy of Sciences* 69, no. 11 (1 November 1972): 3199–3203.

[37] Gabriela Valdivia, Wendy Wolford, and Flora Lu, "Border Crossings: New Geographies of Protection and Production in the Galápagos Islands," *Annals of the Association of American Geographers* 104, no. 3 (4 May 2014): 686–701, 687.

[38] On this reinvention, see Jesse Donahue and Erik Trump, *The Politics of Zoos: Exotic Animals and Their Protectors* (DeKalb: Northern Illinois University Press, 2006) and Bryan G. Norton et al., eds., *Ethics on the Ark: Zoos, Animal Welfare, and Wildlife Conservation* (Washington and London: Smithsonian Institution Press, 1995). See also Nigel Rothfels, *Savages and Beasts: The Birth of the Modern Zoo* (Baltimore: Johns Hopkins University Press, 2002) and David Hancocks, *A Different Nature: The Paradoxical World of Zoos and Their Uncertain Future* (Berkeley: University of California Press, 2001).

long used to acclimatising and perpetuating non-native populations – has happened only relatively recently, gaining increasing momentum after WWII and taking a decisive turn with the Convention on Biological Diversity in 1992. Zoos completed their pivot toward conservation activities with the inception of the World Association of Zoos and Aquariums (WAZA) in 1946, under the name International Union of Directors of Zoological Gardens, and the International Union for the Conservation of Nature (IUCN) in 1948. The 1970s saw the development of legal codes attempting to limit the sourcing of wild animals by zoos, paving the way for the development of captive zoo breeding programs; the WAZA Code of Ethics and Animal Welfare, which explicitly states the need for zoos and aquaria to cooperate with the wider conservation community, was adopted in 2003.[39] The ex situ conservation of wild plant species in seed banks – a practice initially developed for food crops – has seen a similarly rapid and extensive development over the past few decades, and has come to form an important part of many botanic gardens' conservation activities after the formation of the Botanic Gardens Conservation International in the 1980s and the implementation of the Global Strategy for Plant Conservation in 1999.[40]

The Convention on Biological Diversity defines ex situ conservation as the "conservation of components of biological diversity outside their natural habitats."[41] These loosely characterised unnatural habitats "include whole plant or animal collections, zoological parks and botanic gardens, wildlife research facilities, and germplasm collections of wild and domesticated taxa,"[42] a wildly heterogeneous landscape of institutions spanning every possible degree of liveliness, experimentality, and remoteness from the field. A topology as fragmented and wide-ranging as this could hardly be expected to remain static, and this flotilla of "other spaces" has undergone connective transformations similar to the ones that transformed natural reserves into networks vascularized with green corridors. The late 1980s and 1990s were dominated by the so-called "ark paradigm," following an influential appeal by Soulé, Gilpin, Conway

[39] Irus Braverman, "Conservation without Nature: The Trouble with In Situ versus Ex Situ Conservation," *Geoforum* 51 (January 2014): 47–57, 52.

[40] See Kayri Havens et al., "Ex Situ Plant Conservation and Beyond," *BioScience* 56, no. 6 (1 June 2006): 525–31, and Michael F Fay and Maarten JM Christenhusz, "Plant Conservation and Botanic Gardens," in *ELS* (Chichester: John Wiley & Sons, Ltd, 2016).

[41] Convention on Biological Diversity, art. 2.

[42] IUCN, "IUCN Technical Guidelines on the Management of Ex Situ Populations for Conservation" (2002).

and Foose.[43] Their proposal was for zoos around the world to pivot from entertainment and display to the open-ended storage of genetic diversity, in order to weather a projected "demographic winter lasting 500–1,000 years and eliminating most habitat for wildlife in the tropics," after which the authors assume that habitat for wild species will start increasing again.[44] Their article sketched out a framework for the efficient maintenance of sustainable animal populations in zoos and for the ideal allocation of space on what the authors called the "millennium ark," and called for a better coordination of zoo cooperation in their efforts to breed captive species so that at least a fraction of biodiversity might be maintained for future reintroduction. While the authors paid lip service to the necessary maintenance of natural reserves in order to support populations of smaller plants and animals, they were less than sanguine about any short-term improvement of wild habitats, and argued that "it would not be unreasonable to plan for a voyage of 1,000 years."[45] They did, however, revise their projection for zoos to meet their genetic diversity targets in the light of contemporary advances in cryotechnologies and reproductive science, which signalled the possibility of moving large and costly living populations "from the space- and resource-intensive 'living zoo' to the miniaturized, 'suspended zoo' […] replac[ing] the millennium ark with a 'millennium freezer'."[46]

This early attempt at bringing ex situ conservation to bear on the dramatic course of a potential sixth mass extinction event takes place in what Deborah Bird Rose has called the "zone of the incomplete," energised by "Western dreams of stopping, kick-starting, or leaping across time, and from modernity's commitment to achieving eternal perfection here in the world of actual beginnings and endings."[47] While the docking of the millennium ark is predicated on a nebulously defined decline of the human population or the advent of changing of environmental attitudes, it is still rooted in a linear conception of progress and an eschatological understanding of catastrophe and redemption. Ex situ conservation represents an instrument of increased fragmentation, working as it is toward the explicit goal of disjointing life materially and temporally – making use of "the

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43 Andrew E. Bowkett, "Recent Captive-Breeding Proposals and the Return of the Ark Concept to Global Species Conservation," *Conservation Biology* 23, no. 3 (June 2009): 773–76, 774.

44 Michael Soulé et al., "The Millennium Ark: How Long a Voyage, How Many Staterooms, How Many Passengers?," *Zoo Biology* 5, no. 2 (1986): 101–13, 101.

45 Soulé et al., "The Millennium Ark," 106.

46 Soulé et al., "The Millennium Ark," 106.

47 Deborah Bird Rose, "Reflections on the Zone of the Incomplete," in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017), 146.

ability to freeze, halt, or suspend life, and then reanimate," as Hannah Landecker puts it. As she notes in her study of the technical culturing of cells, "the freezer […] acted as a central mechanism both within individual laboratories and companies and within the biological research community more generally to standardise and stabilise living research objects that were by their nature in constant flux […]. In short, to be biological, alive, and cellular means (at present) to be a potential 'age chimaera', to be suspendable, interruptible, storable, and freezable in parts."[48]

For a while this seemed to be the ideal, final transmutation of the deterritorisalising machine that botanic and zoological gardens were supposed to be: the figure of the millennium ark exerted a considerable gravitational pull on zoo practices worldwide, gathering institutions together in the wake of this seminal publication and driving new and unprecedented levels of cooperation between them. Various advisory groups were tasked with measuring available zoo space, regional cooperative programs were put in place, and breeding programs (such as the Species Survival Plans implemented in North America) were established, bringing with them a battery of breeding tools such as studbooks to help keep track of lineages and diversity.[49] The attempt, however, has come up against the complex logistics of breeding sustainable populations in captivity, and the difficulties of implementing the scientific guidelines of the ark paradigm. While seed banks in botanic gardens have encountered less difficulties in propagating for reintroduction and in stocking ample amounts of wild seeds, zoological gardens have seen their ark activity decline somewhat in the twenty-first century, and the question of whether they actually make an efficient contribution to conservation is regularly reopened.[50] The entire ex situ landscape has now reorganised around a more connected, integrated approach, and collaboration with existing in situ conservation efforts and forms of more direct intervention are starting to blur the lines between the

[48] Hannah Landecker, *Culturing Life: How Cells Became Technologies* (Cambridge, Massachusetts: Harvard University Press, 2009), 228. See also Carrie Friese, *Cloning Wild Life: Zoos, Captivity and the Future of Endangered Animals.* (New York: New York University Press, 2013) and Matthew Chrulew, "Freezing the Ark: The Cryopolitics of Endangered Species Preservation," in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017).

[49] See C. M. Lees and J. Wilcken, "Sustaining the Ark: The Challenges Faced by Zoos in Maintaining Viable Populations," *International Zoo Yearbook* 43, no. 1 (January 2009): 6–18.

[50] See for instance the problem of taxonomic bias towards charismatic megafauna discussed in J. E. Fa et al., "Zoos Have yet to Unveil Their Full Conservation Potential," *Animal Conservation* 17, no. 2 (2014): 97–100. See also Jenny Gray, *Zoo Ethics: The Challenges of Compassionate Conservation* (Ithaca: Cornell University Press, 2017).

wild and the ark.[51] Ex situ collections are seen as useful "safety nets" complementing conservation and restoration efforts in the wild rather than safe arks decoupling their charges from extinction in situ.

Ex situ institutions are now reinserting themselves into a lively topology of conservation spaces, and an ecology of practices, looking to collaborate with more emplaced modes of survival and world-making. Their place in this topology, however, remains relentlessly contested, and ex situ conservation is usually juxtaposed unfavourably against its in situ counterpart. Irus Braverman has mapped the "often tense professional relationship between field conservationists, on the one hand, and conservationists who work in captive settings, mostly zoo professionals, on the other hand," and notes that in situ conservation is "usually prioritized by both" (a statement substantiated by most discussion sections of the articles cited in this thesis, which often include a deferential nod to the superior necessity of in situ conservation and habitat preservation).[52] The ex situ/in situ terminology itself was gradually adopted over the last decades to displace more loaded terms:

> Whereas initially adapted from other disciplines to indicate the importance of place for the utility of conservation management of plants in the 1980s, the in situ/ex situ terminology has gained traction as a convenient replacement for the emotionally loaded terms "nature" and "captivity."[53]

Shaped as it has been in the matrix of wilderness thinking, conservation biology – especially in its North American variation – has often failed to include or think with captivity, with species out of place, as an integral part of what conservation biology is or does. The Endangered Species Act of 1973, for instance, does not deem captive species worthy of being included in conservation efforts. Similarly, the IUCN Red List's definitions

[51] "The 'ark paradigm,' the idea that ex situ facilities would hold cultivated stocks of threatened species during a period of habitat degradation, was established as a working objective by botanic gardens in the 1970s. However, the traditional ark model for gardens is no longer sufficient. While ex situ seed storage or cultivation will continue to be an important conservation function, we believe that in order for gardens to operate in a biologically and financially viable manner, the species banking approach must be integrated with a habitat and ecosystem approach. […] Integrated plant conservation […] combines the protection of plants in their native habitats with an ex situ conservation program to provide a safety net against extinction in the wild." (Havens et al., "Ex Situ Plant Conservation and Beyond," 525–31.). See also Joseph Keulartz, "Towards an Animal Ethics for the Anthropocene," in *Animal Ethics in the Age of Humans: Blurring Boundaries of Human-Animal Relationships*, ed. Joseph Keulartz and Bernice Bovenkerk (Berlin: Springer, 2016).

[52] Braverman, "Conservation without Nature," 50.

[53] Braverman, "Conservation without Nature," 49.

exclude animals conserved ex situ: an animal extinct in situ is deemed "non-conserved," even if some individuals are still alive in captivity. But if one thing has become clear, it is that conservation biology is not done reckoning with place and placement, and with the generative proliferations of new relationships, subjects, and abilities that are produced in the liminal spaces of gardens, freezers, and collections.

Braverman's analysis yokes these lively debates around ex and in situ hierarchies to adjacent binaries: nature versus culture, native versus alien, and static versus dynamic. Conservation biology, according to her, is still mired in an unsustainable investment in wild nature, failing to recognise that bodies are fluid and nature is hybrid, that a neat division between ex and in situ places is an outdated form of topology, and that future nature will have to be reinvented and remade.[54] Once again, conservation biology is brought face to face with its problematic foundational categories; this time the call to expunge the term "nature" from the conservationist vocabulary is rooted in an objection to material and conceptual separateness. Such a call, however, only covers part of what is at stake in the fragmentations and reconnections currently transforming the conservationist landscape. Braverman's assessment of the in/ex situ debate, and her castigation of the continued power exercised by the idea of a "pristine nature that exists outside of society" is already somewhat outdated, and guilty of precisely the error pointed out by Stengers in her appeal for the humanities to stay their hand when celebrating the hybrid and innovative too freely or too soon.[55]

It is not necessary to go immediately to the new conservationists (who I will turn to in the last section of this chapter) for confirmation that conservation biology can and must learn to think of its assemblages as dynamic. The field certainly shapes itself around contested borders and situational divides, but even in those debates it would seem that the matter with ex situ spaces is not always their artificiality or separateness, but rather the dangers inherent to their networked, porous nature. This shows, for instance, in the debates emerging around the threat posed by ex situ conservation institutions as materially interwoven with their environment. Botanic gardens are far from sealed and impermeable, and have acted as conduits for many unintentional plant introductions, not

[54] "On one end, in situ is defined as on-site conservation in a wild nature, while on the other end, ex situ is off-site, unnatural, or captive conservation. This definition embodies and naturalizes a few central assumptions: (a) that such wild nature actually exists; (b) that conservation in and of wild nature is always 'in' place, while any other form of conservation is 'out' of place; and (c) that 'in' is normatively preferable to 'out.'" (Braverman, "Conservation without Nature," 46-47).

[55] See Stengers, "Deleuze and Guattari's Last Enigmatic Message."

to speak of the intentional program of introduction, acclimatisation and breeding they furthered in the developed in the eighteenth century as the "exchange house[s]" of European empires.[56] As a consequence, they are emerging as a potential and vigorously debated threat to biodiversity. One example of this debate is the back and forth conducted in 2011 between the ecologist Philip E. Hulme, and the BCGI Director of Global Programmes Suzanne Sharrock. To Hulme's statement that "an increasing body of evidence highlights the possible role of botanic gardens in facilitating plant invasions worldwide, which conflicts with an otherwise high conservation profile" and that "botanic gardens have been implicated in the early cultivation, local dissemination and/or introduction into one or more global biodiversity hotspots of half the environmental weeds listed by IUCN as among the worst invasive species worldwide,"[57] Sharrock and the members of the Botanic Gardens Invasive Species Management Discussion Group have responded with a statement concerning the value of botanic gardens for biodiversity conservation. They note that "[a]ccording to the International Union for the Conservation of Nature, the number of extinct plant species would be 34% higher were it not for those preserved in gardens" and that "in Europe, the European Botanic Gardens Consortium has established an alien plants initiative to identify emerging problem taxa from within the large and diverse botanic collections in European gardens, to alert collection holders to their potential risk of invasiveness."[58] This recasts botanic gardens as key assets in mitigating invasive plant spread rather than the culprits of that spread. In his response, Hulme points out that "[d]espite the fact that botanic gardens no longer have a colonial mandate to acclimatise economic crops," the legacy of botanical imperialism is carried on by living collections, which contain a disproportionate number of species with prior histories of invasion. He warns against complacency and emphasises that botanic gardens have a continued responsibility in preventing plant invasion, noting that "[a]s the distinction between botanic gardens and the wider

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[56] The phrase is Joseph Banks's, at the time director of Kew Gardens under George III (cited in Andrea Wulf, *The Brother Gardeners: Botany, Empire and the Birth of an Obsession* (New York: Random House, 2011), 208).

[57] Philip E. Hulme, "Addressing the Threat to Biodiversity from Botanic Gardens," *Trends in Ecology & Evolution* 26, no. 4 (April 2011): 168–74, 168.

[58] Suzanne L. Sharrock, "The Biodiversity Benefits of Botanic Gardens," *Trends in Ecology & Evolution* 26, no. 9 (September 2011): 433, 433.

horticulture industry becomes increasingly blurred, it is imperative that the former set the highest standard of best practice."[59]

While these debates still hinge on a hierarchised dichotomy between native and invasive, they also recast botanic gardens as active elements in plant ecology, whose danger (and, as we will see in the next chapter, promise) lies precisely in their disaggregating function and accelerative power – in other words, in their ability to modify metabolisms and ecologies in different modes than other conservation practices. I cite this debate to illustrate how conservationists are already contending with the long history of in and ex situ imbrications, and acknowledging that simplistic dualisms are not sufficient to discuss the promise and danger of various conservation projects. Ignoring this engagement with hybrid spaces and practices and concluding, as Braverman does, that the differences between ex and in situ conservation should not only be softened into a continuum but erased entirely is a shortcut that leads straight into a flattened landscape of commensurable bodies and lives, unaffected by the metabolic and technological context in which they become a "liquid nature" more suited to neoliberal market logics than to any critical geography of nonhuman lives and becomings.[60] Whether or not what is in situ ought to be labelled "nature," the differences structuring the conservationist landscape, and the various textures and speeds different practices and institutions allow for, are of crucial and generative importance.

Generally speaking, ex situ spaces are of interest because of *both* their liminality and their connectedness; insisting on the latter as an object of critical attention does not mean that the importance of the former can be disregarded. They are heterotopias, *other* spaces par excellence, where attention is redirected and subjects remade, technological and semiotic apparatuses that allow for manipulations of space, time and genealogies that cannot be reduced to a comparison with an increasingly managed and transformed "wilderness."[61] Only by keeping the hinge between in and ex situ open, and paying critical attention to how transactions and circulations between the two are being reconfigured, can we attend to how this difference makes them political actors, allowing them to intervene in the decoding and recoding of flows (displacing and circulating plants and

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[59] Philip E. Hulme, "Botanic Garden Benefits Do Not Repudiate Risks: A Reply to Sharrock et Al.," *Trends in Ecology & Evolution* 26, no. 9 (September 2011): 434–35, 434.

[60] Bram Büscher, "Nature on the Move I: The Value and Circulation of Liquid Nature and the Emergence of Fictitious Conservation," in *Nature Inc.: Environmental Conservation in the Neoliberal Age*, ed. Bram Büscher, Wolfram Dressler, and Robert Fletcher (Tucson: University of Arizona Press, 2014), 138.

[61] See Michel Foucault, "Of Other Spaces," trans. Jay Miskowiec, *Diacritics* 16, no. 1 (1986): 22–27.

animals always comes with a translation of information; even in the deep freeze, nothing remains static), and function as centres of calculation and sites of biosocial becomings – reactivating, rewiring, reworlding.[62] And no ex situ institution, practice or proposal can be entirely subsumed under a unified agenda or ideology; as Rodney Harrison reminds us, "biodiversity conservation […] is in fact a diverse and heterogeneous field in which there is significant variability in approaches, conservation philosophies, techniques, and technologies."[63] Nature is certainly being reinvented ex situ, or rehearsed, but this always occurs *differentially*, through a set of practices and proposals that are never commensurable and often conflicting.

4. Histories of Displacement: Several Brief Genealogies of Conservation

These debates show the importance of a wider historical perspective on ex situ institutions; before I come back to the transformative processes taking place ex situ, a brief detour through methodological considerations of a historico-topological (or, to put it differently, archaeological) nature is in order. By this I mean not a history of ideas or a genealogy of ethics, as Callicott has attempted to trace, but an overview of the material transmutations that have influenced the field's process of individuation as a discipline.

In my quick sketch of conservation biology's origin drama (or epic, depending on who is telling it), I have presented what most histories of conservation biology – often written by its own practitioners – would call the facts. Most of them would characterise the formation of this discipline as a break, as a form of decisive novelty in the wider history of the ecological and biological sciences. But the history of conservation biology could also be written otherwise, by resituating it into the context of several possible histories, which can be told in concentric circles rippling further and further away from the present moment, or as a patchier list of practices whose heritage partially overlaps in conservation biology as it emerged at the end of the twentieth century. The former would result in a potentially teleologically ordered chronology, which is precisely what I wish to avoid in this account; the latter, we will see, might prepare the ground for a more

[62] On coding and decoding, see Deleuze and Guattari, *A Thousand Plateaus*. On centers of calculation, see Latour, *Science in Action*.
[63] Rodney Harrison, "Freezing Seeds and Making Futures: Endangerment, Hope, Security, and Time in Agrobiodiversity Conservation Practices," *Culture, Agriculture, Food and Environment* 39, no. 2 (December 2017): 80–89, 80.

properly genealogical approach to transformative conservation, one that is not concerned with the search for a chronologically coherent origin but rather with the transformations and reconfigurations of inherited practices when conservation biology is challenged anew by controversial proposals.

Gardens, for instance, and their utopian displacement of a curated and highly managed nature into an Edenic enclosure, are one site where ex situ conservation emerged. Histories of botanic gardens – where most of today's wild seed banks are located – often reference this genealogical strand, some of them reaching back to examples as remote in time and space as Chinese and Aztec botanic gardens.[64] The physic garden and pleasure grounds both provide templates for the development of the most prominent European botanic gardens as we now know them, and their offshoots in almost every country in the world: as Roger Spencer and Rob Cross note, "the oldest existing botanic gardens date back to the early modern period, to the educational physic gardens associated with the medical faculties of universities in sixteenth-century Renaissance Italy," although "today's botanic gardens have little to do with these early and highly specialised medicinal gardens whose narrow academic and scientific goals and formal designs have subsequently taken on additional economic, environmental, aesthetic and other values."[65] Horticultural care is one of the templates for relationships with endangered plants as they are now emerging and being negotiated in botanic gardens; wild species are brought into a regime of highly refined management that was developed for the cultivation of beauty, mutations and adaptability rather than the preservation of species in a supposedly static and untouched state.

Zoological gardens have followed similar transmutations since their first incarnations as menageries or stocks of beasts for games and hunting, which Eric Baratay and Elisabeth Hardouin-Fugier date back to the capture of wild animals for Ancient

[64] "The Chinese, however, should, as might be supposed, be credited with being the real founders of the idea of botanic gardens, since it is clear that collectors were despatched to distant parts and the plants brought back were cultivated for their economic or medicinal value [...]. New Spain, indeed, furnished more important species of medicinal plants perhaps than any other part of the world, and their virtues were understood by the Aztecs, who are credited with having studied medical botany as a science. The gardens at Iztapalan and Chalco are said to have been stocked with trees and plants scientifically arranged, and the gardens at Chalco, which were preserved after the Conquest, furnished Hernandez with many of the specimens described in his book." (Arthur W. Hill, "The History and Functions of Botanic Gardens," *Annals of the Missouri Botanical Garden* 2, no. 1/2 (1915): 185–240, 186).

[65] Roger Spencer and Rob Cross, "The Origins of Botanic Gardens and Their Relation to Plant Science, with Special Reference to Horticultural Botany and Cultivated Plant Taxonomy,"', *Muelleria* 35 (25 August 2017): 43–93, 43.

Roman *bestiarii*. This history of zoos goes back even further than the first proper menageries – royal, noble, and ecclesiastical – containing both "ferocious" show animals and hunting stock, and acting as symbols of power and status. These menageries also functioned as a stock of exchange tokens between sovereigns, with rare and exotic animals circulating as diplomatic gifts or tributes across continents. Trade routes were, unsurprisingly, the roads along which exotic animals travelled, at least since the fifteenth century; Baratay and Hardouin-Fugier note that the Dutch East India Company, for instance, became an important part of the zoological *agencement*.[66] Royally mandated expeditions to collect exotic animals became the basis for the menageries, which in turn provided the material for what we now know as zoological gardens, such as the one at Versailles or the menagerie at Schönbrunn, leading Baratay and Hardouin-Fugier to state that "the most significant development of modern times for the history of zoos lies in the growing influx of exotic animals caused by the expansion of trade and the great discoveries of the fifteenth and sixteenth centuries."[67] This in turn points us to the great setting into flux that was colonial exploration, which has played a foundational role in establishing the institutions in which collected material came to be accumulated and organised under regimes of display, power and care. Ex situ conservation is predicated on the existence of a material structure that can organise plants and animals into lives of confinement and management, but also on a world remade so that species, now fungible commodities, can be dissociated from their native ecosystems and travel across the planet unshackled from the slower rhythms of geological movements, climatic range shifts, pollination, seed dispersal and seasonal or seasonal migration. Botanic and zoological *expeditions* thus played a defining role in the emergence of botanic and zoological *gardens,* reordering both what nature was and what it could do. From the first mail-ordering of plants for cultivation and acclimatisation in Britain (as practised, for example, by Peter Collinson, with the help of John Bartram) to Joseph Banks' participation in Cook's voyages on a massive cataloguing and sampling mission of the world's flora,

[66] "Thus the Dutch East India Company became the main supplier for north-western Europe. The Company had sheds built on the quays of Amsterdam's port which served as holding pens before sale. The Company's importance is apparent, for example, in the work of the Dutch scholar Peter Camper, who was able to cite the origins of the exotic animals he described" (Éric Baratay and Elisabeth Hardouin-Fugier, *Zoo: A History of Zoological Gardens in the West* (London: Reaktion Books, 2002), 22).
[67] Baratay and Hardouin-Fugier, *Zoo,* 29

colonial botany and zoology played a crucial role in the establishment of many ex situ institutions as we know them now.[68]

One last practice that has lent its methods and concerns to conservation is agriculture, which some publications suggest as the original source of conservation practices – a genealogy that would root the technological advances making the ex situ conservation of wild species possible in the earliest relationships of domestication forged between humans and nonhuman species. Spencer and Cross, for instance, go back all the way to the Neolithic:

> To understand today's cultural landscapes in general, and botanic gardens in particular, we must go back to the very beginnings of plant cultivation and the origins of domesticated plants [...]. Agriculture provides the big-picture backdrop to the history of botanic gardens not only because it now underpins all human existence as a source of sustenance, but because it produced the surplus wealth that facilitated the urbanisation and civilisation from which botanic gardens would emerge.[69]

This is not an entirely unreasonable genealogical account, as seed saving and animal husbandry practices are cultural and technological prerequisites for what ex situ conservation now does – the exercise in displacement and re-placement, in suspension and stockpiling enabled by agriculture appearing as a first rehearsal of practices perpetually enlarged, accelerated and transformed throughout history, and ultimately transposed to the conservation of endangered wild species. The unbroken line traced by the authors from the first domestication of plants to urbanisation, the beginnings of large-scale urban gardening, and the rise of colonial botany, while prone to a few sweeping generalisations, shows how successive concerns and demands have reconfigured the paradigms of plant breeding and management, and how inextricably intertwined the histories of these concerns are. I will explore a perhaps less grandiose version of their assertion that "we can trace a loose historical path and connection between shaman-medicine-man, priest, physician, philosopher, herbalist, apothecary, pharmacist, professor of botany, the intellectually curious man of means and leisure, professional botanist… to general managers with botanical, horticultural or other administrative

[68] On the intertwined history of zoological gardens and colonisation, see also Rothfels, *Savages and Beasts* and Robert J. Hoage and William D. Deiss, *New Worlds, New Animals, From Menagerie to Zoological Park in the Nineteenth Century* (Baltimore and London: Johns Hopkins University Press, 1996).

[69] Spencer and Cross, "The Origins of Botanic Garden," 44.

background" in the following chapters.[70] For now, let me just note that recent seed banking history seems to have recapitulated the movement from agriculture to conservation – the first seed banks created in the US were part of the breeding programmes of the Office of Foreign Seed and Plant Introduction, established in 1898. This agricultural history even coloured initial perceptions of conservation, so much so that "because of the predominance of ex situ conservation in the history of agriculture, conservation was initially characterized as a utilitarian practice."[71]

[70] Spencer and Cross, "The Origins of Botanic Gardens," 91.

[71] Braverman, "Conservation without Nature," 46. On the significance of seed banking in agriculture, see also Helen Anne Curry, "From Working Collections to the World Germplasm Project: Agricultural Modernization and Genetic Conservation at the Rockefeller Foundation," *History and Philosophy of the Life Sciences* 39, no. 2 (June 2017).

II. An Inquiry into Transformative Conservation

1. What Scientists Say

The previous section provided only a quick overview of the many strands braided into ex situ conservation practices; I will come back to these overlapping histories in more detail and unfold them further in my analyses of assisted migration, crop wild relative conservation, and assisted evolution. For now, this historical excursus necessitates a methodological explanation. As I noted above, my point in sketching out the various possible genealogies of the current configuration of conservation is not to suggest that there is an unbroken line between contemporary conservation biology and other structures of power over nonhuman lives, or to argue that contemporary shifts in conservation biology are nothing but surface phenomena concealing the fact that the structure of the discipline is still that of a sovereign, spectacular power unchanged since the days of colonial extraction and menageries. The latter has been identified as one element in the protracted debate between Foucault and Derrida on the subject of the historicity of thought, as staged for instance in *The Beast and the Sovereign*.[72] This is of particular interest to my inquiry for its emphasis on how to approach novelty, the passing of historical thresholds, within conservation biology – a space in which it would be tempting to see nonhuman animals (and plants even more so) merely as interchangeable symbols for the operations of sovereign power. In contrast, my approach is in part informed by Foucauldian archaeology or genealogy, in which the use of historiographical elements, both discourse and practice, is not a method

> treating discourses as groups of signs (signifying elements referring to contents or representations) but as practices that systematically form the objects of which they speak. Of course discourses are composed of signs, but what they do is more than use these signs to designate things. It is this more that renders them irreducible to language and to speech. It is this "more" that we must reveal and describe[.][73]

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[72] See Matthew Chrulew, "'An Art of Both Caring and Locking Up': Biopolitical Thresholds in the Zoological Garden," *SubStance* 43, no. 2 (1 January 2014): 124–47.

[73] Michel Foucault, *The Archaeology of Knowledge,* trans. A.M. Sheridan Smith (New York: Pantheon Books, 1972), 49.

This empiricism allows scientific discourse and practices to become conceptual elements in their own right, without assigning them to pure textuality; a distinction which allows me to circumvent – but also, hopefully, to clarify – the largely fruitless war over the reality of nature and the validity of the practices designed to protect this nature with which I opened this chapter.

The methodology I am following here is not one of hermeneutic excavation, a strategy which would allow me to position myself above the discourse and practices I am studying – as if I had anything to teach naïve conservationists, or something like a secret origin or a deeper, more sober truth to uncover beneath what they purport to do. This comes back to Chaloupka and Cawley's statement I quoted above: conservation biology is indeed doing something else than what its practitioners say, but it is a strategic rather than a repressive or unconscious gesture. In order to legitimise itself, conservation biology must present "utopian generalizations of nature" – which is an "open secret" among wilderness advocates according to Chaloupka and Cawley:

> The open secret is not necessarily a weakness of the wilderness advocates, as long as it holds. It must remain open – available to every advocate, well enough known that the role of teacher is allocated to the wilderness countersite in political discourse. But that message must also remain secret – unspoken in any direct way – because it introduces a dangerous contradiction to that political message.[74]

Their reading of conservation issues through the lens of a Foucauldian concept of heterotopia allows Chaloupka and Cawley to analyse wilderness reserves not as disconnected Utopian ideals of nature but as sites where resistance and oppositional politics (and also, often, politics complicit with dominant operations of power) can be assembled and articulated. Politicising conservation practices entails an analysis of the political moves they are making in reconstituting various sites for experimentation and contestation, and of how these gestures are grounded in the rhetorical use of heterogeneous historical elements. As Foucault lays out in *The Archaeology of Knowledge*:

> The third purpose of such a description of the facts of discourse is that by freeing them of all the groupings that purport to be natural, immediate, universal unities, one is able to describe other unities, but this time by means of a group of controlled decisions. Providing one defines the conditions clearly, it might be legitimate to constitute, on the basis of correctly described

[74] Chaloupka and Cawley, "The Great Wild Hope," 11.

> relations, discursive groups that are not arbitrary, and yet remain invisible. Of course, these relations would never be formulated for themselves in the statements in question (unlike, for example, those explicit relations that are posed and spoken in discourse itself, as in the form of the novel, or a series of mathematical theorems). But in no way would they constitute a sort of secret discourse, animating the manifest discourse from within; it is not therefore an interpretation of the facts of the statement that might reveal them, but the analysis of their coexistence, their succession, their mutual functioning, their reciprocal determination, and their independent or correlative transformation.[75]

This also means that I am not seeking to unveil the past by digging up previously hidden or secret relationships, or to seek the repressed prehistoric or agricultural past of conservation practices, or to read them *against themselves* for something that is more interesting precisely *because* repressed. It also follows from this that conservation practices are *not metaphors*. Whenever I extend my analysis of one transformative proposal into a more speculative mode, I am not claiming to formulate either pre-existing assumptions or deeper truths about conservation practices. Transformative conservation proposals are not the return of the conservationist repressed, and I do not mean to suggest that conventional conservation biology must be liberated from its own blindness. Deleuze, suggesting the possibility of replacing a psychoanalytic reading with a cartographic one, proposes a provocation for psychoanalysis and literary studies that might very well prove a useful tool for integrating a historical perspective into an analysis of the forms of power and agency that are produced rather than obscured by conservation practices:

> A cartographic conception is very distinct from the archaeological conception of psychoanalysis. The latter establishes a profound link between the unconscious and memory: it is a memorial, commemorative, or monumental conception that pertains to persons or objects, the milieus being nothing more than terrains capable of conserving, identifying, or authenticating them. […] Maps, on the contrary, are superimposed in such a way that each map finds itself modified in the following map, rather than finding its origin in the preceding one […]. Every work is made up of a plurality of trajectories that coexist and are readable only on a map, and that change direction depending on the trajectories that are retained.[76]

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[75] Foucault, *The Archaeology of Knowledge*, 29.

[76] Gilles Deleuze, *Essays Critical and Clinical*, trans. Daniel W. Smith and Michael A. Greco (London, New York: Verso, 1998), 63.

My critique of conservation proposals does not rest on the idea that they are not explicit enough about the kind of power they are looking to exert, but that their very explicitness, especially in emergent transformative proposals, is what must be questioned and analysed as a potential alignment with the "infernal alternatives" manufactured by contemporary governance.[77]

While my approach to examining the strategies of conservation proposals is decidedly non-heroic, it does not renege on the promises of feminist, queer, or decolonial scholarship, and is not invested in neutrality or distance. It is also one attempt at finding a rhetorical strategy adequate to the historical context woven into the entirety of this work, which started less than a month before the 2016 US presidential election and concluded during the global COVID-19 pandemic. These years in between have been marked by the profoundly poisonous rise of "post-truth" politics, in which quite a few intellectuals once involved in the Science Wars have been forced into a reckoning with the "strange bedfellows" their own unquestioned practices have left them with.[78] As we will see, transformative conservation practices also carry in them the potential for subversive ways of composing and living together. These possibilities emerge from conservationist discourse itself, and while they necessitate new forms of *cartography* – placing them in contact with concepts or discourses they are not necessarily already in dialogue with – this need not be understood as a form of *decoding*. Not excavation but recontextualisation: what must be highlighted critically is not buried or past but always *alongside*. And, as Isabelle Stengers has observed time and again in her critical engagement with scientific and technological practices, it is the alliances that make the poison, or the cure.

2. Ex situ Technologies

As I have mentioned in the preceding discussion of the ark paradigm, ex situ institutions have refashioned themselves into conservation actors partly on the promissory power of emerging technologies, a process through which, according to Ben Minteer, Jane Maienschein, and James P. Collins, "[s]ome zoos developed into 'boundary

[77] Isabelle Stengers, *In Catastrophic Times: Resisting the Coming Barbarism*, trans. Andrew Goffey (London: Open Humanities Press, 2015), 9.
[78] Stengers, "Deleuze and Guattari's Last Enigmatic Message," 155.

institutions' using translational research to move the best ideas and most advanced techniques that modern science had to offer from laboratory or field experiments to conserving Earth's biodiversity."[79] While the colonial iterations of the zoological and botanical garden were already experimental spaces, ex situ conservation has been enriched with a variety of technoscientific tools that seem to fulfil the promise of suspending decay, reducing space, and surviving time made by these other spaces in the face of rapidly contracting in situ possibilities. There are two strands to these new extensions of ex situ capabilities. They are partly informed by advances in genetic sciences,[80] which have driven a "molecular turn" in conservation biology, making genes objects of conservation in themselves and invigorating new conservation geographies through phylogenetic tracing.[81] The applications of genetic science in ex situ conservation range from the possibility of characterising accession diversity to transformations in breeding practices, and to more direct interventions such as cloning. These genetic technologies are complemented by the increasingly sophisticated possibilities of cryopreserving endangered species, which have driven research into the preservation of different animal gametes, made the vitrification of recalcitrant seeds possible, and culminated in the establishment of several high-profile freezing facilities, chief among them the Millennium Seed Bank at the Royal Botanic Gardens, Kew and the Frozen Zoo® at the San Diego Zoo Institute for Conservation Research. Manipulating temperatures, and in particular extreme temperatures, has become an important tool in the technological arsenal of ex situ conservation.[82] Thus the uneasy dream of a "millennium freezer" expressed by Soulé and his colleagues at a time when these possibilities were merely projected, seems to have been realised.

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[79] Ben A. Minteer, Jane Maienschein, and James P. Collins, eds., "Zoo and Aquarium Conservation: Past, Present, Future," in *The Ark and Beyond: The Evolution of Zoo and Aquarium Conservation* (Chicago: University of Chicago Press, 2018), 4.

[80] See Stephanie J. Galla et al., "Building Strong Relationships between Conservation Genetics and Primary Industry Leads to Mutually Beneficial Genomic Advances," *Molecular Ecology* 25, no. 21 (2016): 5267–81. The authors call for intensified collaboration between geneticists and primary industry scientists (working in agriculture, fisheries, forestry and horticulture) in order to drive genomic research and the more efficient estimation of the genetic structure and gene flow of endangered populations.

[81] A term used by Elisabeth Hennessy in her study of the "ramifications of genetic science on the practices and policies of conservation" (Elizabeth Hennessy, "The Molecular Turn in Conservation: Genetics, Pristine Nature, and the Rediscovery of an Extinct Species of Galápagos Giant Tortoise," *Annals of the Association of American Geographers* 105, no. 1 (2 January 2015): 87–104).

[82] See Chrulew, "Freezing the Ark," for an account of how artificial temperature optimisation has developed in zoo biology.

Critical studies of conservation biology have started exploring the implications of these new articulations. Here we may again return to Deborah Bird Rose's warnings about the techno-optimism of redemptive technologies, which produce a time that is "unilinear, monological, and teleological"; in her reading of cryotechnologies, conservation biology is enacting a dangerous secularised version of messianic time, foregoing the possibility of care and ethical attention here and now in favour of the redemptive power of these death-suspending apparatuses.[83] That the suspensive nature of ex situ conservation should have exerted such a pull on environmentally-oriented scholarship is no surprise; institutions such as the Frozen Zoo® and the Millennium Seed Bank rely on the slick and compelling aesthetics of the deep freeze in order to justify their activities and attract attention and funding.

Critiques such as Rose's provide a valuable entry point into the question of how and where conservation biology has been overtaken by technological innovation. This issue has emerged at the intersection of critical engagement with the technological extensions of interspecies relationships and anthropological and science and technology studies literature on biotechnologies and their effect on reordering life. In the Foucaldian perspective on the emergence of biopower as a dominant form of governance often adopted by the latter, the relieving of natural history by the biological sciences signalled an epistemological and ontological shift from nature (the visible surface of beings that can be classified taxonomically on the basis of their appearance) to biology (a movement into the depths of the "hidden structures […], buried organs, [...] invisible functions" of the animal organism[84]). This transformation is now compounded and extended by the emergence of molecular biology, which recasts life as information and the "postvital" body as the container and expression of genetic information.[85] Donna Haraway has traced the process and ramifications of what she calls genetic fetishism, the enabling of "a specific kind of mistake that turns process into nontropic, real, literal things inside container." In her account, the gene as the "master molecule" is a technoscientific achievement obscuring the complex sociotechnical processes of work and the interactions between a host of human and nonhuman actors necessary to bring it into

[83] Rose, "Reflections on the Zone of the Incomplete", 148.
[84] Michel Foucault, *The Order of Things. An Archaeology of the Human Sciences* (New York: Pantheon Books, 1970), 277.
[85] See Richard Doyle, *Wetwares. Experiments in Postvital Living* (Minneapolis: University of Minnesota Press, 2003).

being.[86] In a similar vein, Hannah Landecker has argued that the becoming-cellular (and by extension, the becoming-molecular) of life cannot be separated from the infrastructural innovations enabling its suspension and standardisation: "sometimes the freezer matters more than the species, or the medium more than the type of cell cultured in it."[87] Cells, and by extension genetic information, do not simply emerge as alienated, standardised and fungible objects; they are made so by a host of new technologies such as freezing and thawing, stopping, starting and synchronising cell development, or enucleating, which all exploit an organismic plasticity that has been the focus of the biological sciences since the 1900s. In turn, these techniques build up until they are formalised into what Landecker calls "unarticulated assumptions" about plasticity and temporality, and what it means to be biological. Cells and organisms now exist in a significantly transformed time-scape, as "[b]eing cellular after cloning entails a different sense of biology and time: what is lost is the assumption of biological progression being yoked to historical time in any given, predictable way."[88]

When it comes to counter-extinction practices, the rise of molecular biology, linked as it is to cryopreservation and an increasing emphasis on ex situ gene banking practices, means that "storing genetic information is seen to constitute an important part – perhaps in some ways even a sufficient one – of 'saving' a species."[89] The extension of technological possibilities for intervening in nonhuman lives transforms the politics of ex situ conservation: the preservation of genetic material is recast as a moral obligation to intervene into extinction processes, and reduces the need for large captive populations, or even living animals at all.[90] The effect of physiological suspension and circulation has ramifications touching on our very understanding of what extinction means: Thom van Dooren, for instance, has explored the consequences of being able to maintain last individuals, concluding that what "these banks actually freeze and delay is not so much extinction itself, but rather the *recognition* of extinction, the recognition that something significant has already been lost. Single individuals or declining populations stand in for

[86] Donna Haraway, *Modest_Witness@Second_Millennium. FemaleMan_Meets_OncoMouse: Feminism and Technoscience* (New York and London: Routledge, 1997), 136.
[87] Landecker, *Culturing Life*, 224.
[88] Landecker, *Culturing Life*, 232. On the seeming immortality and endless circulation of new materials and entities in the Anthropocene, see Michelle Bastian and Thom Dooren, "Editorial Preface: The New Immortals: Immortality and Infinitude in the Anthropocene," *Environmental Philosophy* 14 (1 January 2017): 1–9.
[89] Chrulew, "Freezing the Ark," 292.
[90] Chrulew, "Freezing the Ark," 286.

this thing called a species, keeping it off the official listings of the departed."[91] The proxy-making work of ex situ conservation has been explored by Esther Breithoff and Rodney Harrison, who argue that the spatial disarticulation of captivity is exacerbated by an increasingly extended technological apparatus. This enables ex situ institutions to make "certain kinds of biological materials, in combination with different forms of data pertaining to those materials, come to stand in for the species from which those materials have been taken."[92]

It is hardly disputable that the scientific and technological advancements integrated into the conservationist agenda also increase the fungibility of dis- and re-membered bodies or populations. Incorporating molecular biology and cryopolitics into an extended Foucauldian framework of interspecies biopolitics is vital for grasping how conservation biology reconfigures space, time, and relationships. But I am wary of lending too much weight to the idea, threading explicitly or implicitly through many accounts of captive and suspended wildlife, that both genetic technologies and ex situ cryopreservation seek or enable a form of immortality. Haraway speaks of genes as the "undead things" that come to supplant the "lively subjects" they stand in for, and her concept of genetic fetishism reappears in Rose's reading of thermal politics as messianic time or Chrulew's analysis of how cryopower "secure[s] life against *living itself*."[93] Warwick Anderson proposes a parallel reading of cryotechnologies, through a Derridean lens, as an attempt to attain "absolute immunity," and suggests that they open the possibility of destroying or forgetting the person and so "to turn donors into future things, immortal things, to accumulate novel collectivities with artificial modes of association or biosociality – in other words, to ontologize the remains, to make present the partible."[94] There is not much space in the freezer or the seed bank for the work of

[91] Thom Van Dooren, "Banking the Forest: Loss, Hope, and Care in Hawaiian Conservation," in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017), 274.
[92] Esther Breithoff and Rodney Harrison, "From Ark to Bank: Extinction, Proxies and Biocapitals in Ex-Situ Biodiversity Conservation Practices," *International Journal of Heritage Studies*, 5 September 2018, 1–19, 8-9.
[93] Chrulew, "Freezing the Ark," 299.
[94] Warwick Anderson, "The Frozen Archive, or Defrosting Derrida," in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017), 247.

maintaining a species as a social achievement,[95] or for the necessary transmission of intergenerational knowledge.[96]

While Landecker's tracing of the emergence of immortality as a scientific project and her analysis of its centrality in the development of cellular and molecular technologies are convincing,[97] adopting this concept as the sole lens through which to interpret an entire field of conservation practices seems too partial, and runs the risk of cleaving too closely to the public rhetoric mobilised by these institutions to define what they are doing for a general audience.[98] As I have already noted, the connective landscape of conservation biology means that abstracting one single infrastructural element is always a fraught enterprise, allowing one aspect of conservation to act almost independently from the context in which it has emerged. The bank or freezer are always placed inside a more extended institution. As Chrulew reminds us, "amid multiple migrations and transformations of techniques and biological materials – between zoo and wild as much as between zoo and lab – it remains to be seen what effect the frozen ark might have on the other vessels in the zoological flotilla."[99] If we assume that these technologies are themselves elements in the biosocial becomings of endangered species, suspension can be studied for what it produces rather than forecloses.

On this basis, I approached ex situ conservation spaces and practices guided by the assumption that something other than immortality was at stake when the "idea of biological time not as a boundary but a moveable – plastic – quality" is enabled.[100] Kay Lewis-Jones, in her meticulous ethnographic work on the Millennium Seed Bank Partnership, presents one possible blueprint for such a modified approach. She analyses the seed bank as a liminal space, drawing on both Foucault's concept of heterotopia and Turner's work on liminal rites of passage. This allows her to investigate the cultural and social significance of spaces in which time is slowed or stopped and gaps in everyday

[95] As explored in Thom Van Dooren, *Flight Ways: Life and Loss at the Edge of Extinction* (New York: Columbia University Press, 2014).

[96] Chrulew explores this issue through the objections formulated by the Swiss zoo director Heini Hediger, who saw cryobanking as a "dead end" admitting no transmission of cultural learning between animals and therefore no proper ethopolitical care for them in the zoo (Chrulew, "Freezing the Ark," 300).

[97] Landecker, *Culturing Life*, 71

[98] See for instance the call for "a botanic garden-centered global system that can prevent species extinctions *in perpetuity,*" emphasis mine (Ross Mounce, Paul Smith, and Samuel Brockington, "Ex Situ Conservation of Plant Diversity in the World's Botanic Gardens," *Nature Plants* 3, no. 10 (October 2017): 795–802, 795)

[99] Chrulew, "Freezing the Ark," 299.

[100] Landecker, *Culturing Life*, 230

relational processes opened. In her reading, what is significant about the possibility to preserve and circulate the germplasm is the slowing down of processes, not their complete suspension. Banking seeds is less about preserving them as immortal proxies and more about making them available for experimental reconfigurations of social relations:

> [t]hrough the research facilitated by the [Millennium Seed Bank], the seed collections provide an opportunity to think slowly with each species – potentially for centuries. Having the seed bank enables the potential presence of plants, not just in the form of individuals in a garden, but as functioning populations returned to ecosystems. This capacity suspends species on the edge of extinction, holds them in the world and endeavours to keep their futures open without committing them to any single trajectory.[101]

When the newly extended technological possibilities of ex situ institutions are placed into a heterotopology of conservationist spaces, we see how the suspensive elements of its apparatus are influenced, distorted and transformed by the pull of the various research projects and conservation proposals they are enrolled into, all of which make use in some way of the physiological and temporal gap enabled by these technologies.[102] The transformative history of conservation biology is in the process of being mobilised in novel and often controversial projects, all of which may yet redefine how ex situ conservation can function or intervene, and what kind of objects and subjects it could or should produce.

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[101] Kay E. Lewis-Jones, "Holding the Wild in the Seed: Place, Escape and Liminality at the Millennium Seed Bank Partnership," *Anthropology Today* 35, no. 2 (April 2019): 3–7, 7.

[102] As already mentioned, I borrow this conceptual framework from Foucault, "Of Other Spaces." While Foucault only provided a brief and contradictory sketch of the concept of heterotopia, a counter-site or effectively enacted utopia which represents and inverts all the other sites of a given culture, it has exerted a long-lasting fascination on scholars from a variety of disciplines, especially in the context of the so-called "spatial turn" in social theory. See for instance Kevin Hetherington, *The Badlands of Modernity: Heterotopia and Social Ordering* (London, New York: Routledge, 1997), Edward Soja, "Heterotopologies: A Remembrance of Other Spaces in the Citadel-LA," in *Postmodern Cities and Spaces*, ed. Sophie Watson and Katherine Gibson (Oxford: Blackwell, 1995), 13–34, Robert Rotenberg, *Landscape and Power in Vienna* (Baltimore and London: Johns Hopkins University Press, 1995), and Matthew Gandy, "Queer Ecology: Nature, Sexuality, and Heterotopic Alliances," *Environment and Planning D: Society and Space* 30, no. 4 (1 January 2012): 727–47. For accounts of the afterlife of the concept and critical analyses of its usage, see for instance Kelvin T. Knight, "Placeless Places: Resolving the Paradox of Foucault's Heterotopia," *Textual Practice* 31, no. 1 (2 January 2017): 141–58, and Peter Johnson, 'The Geographies of Heterotopia', *Geography Compass* 7, no. 11 (1 November 2013): 790–803.

3. Experimental Practices

"You are standing in the world's most biodiverse location": this information is imparted to me by a series of yellow posters splashing bright spots of colour across the freezer doors at the Millennium Seed Bank, and catching my eye as I trailed behind Christopher Cockel on my visit to the facilities at Kew – one of the sites where I conducted in-person interviews with researchers and staff involved in transformative conservation projects. This is a catchphrase with its tongue firmly planted in cheek, and yet one I have learned to take seriously as a signifier of the interspecies politics practiced ex situ. It is what Lewis-Jones does when she suggests that the Millennium Seed Bank partnership "might foster a liminal space and summon a sense of communitas, bringing together humans and plants,"[103] and her ethnographic approach to wild seed banking shows that institutions such as the Millennium Seed Bank do not function purely as storage space for suspended and fungible entities.[104] Even if these spaces bank a free-floating "biodiversity," they also allow for forms of material reconfiguration and agential collaboration, and as such represent spaces in which the social lives of plants and animals can sometimes intersect, mingle and rearrange each other. As Breithoff and Harrison suggest in their critical study of natural heritage conservation at the Frozen Ark, banked collections are themselves a "field":

> The genetic material kept at the Frozen Ark is not only harvested from living and dead animals in the 'wild' (often national parks and other protected areas), but also from zoos, aquaria and other ex-situ living collections. […] [W]e suggest that late modern "fields" might not always be remote, as in Latour's model of the history of the modern field sciences, but might instead constitute proximal spaces from which certain resources might be harvested

[103] Lewis-Jones, "Holding the Wild," 6.

[104] This is why I have by and large excluded places such as the Svalbard Global Seed Vault from chapter 3, which touches on agricultural seed banking. Charismatically placed as it is at the intersection of agricultural and conservation concerns, cryopreservation techniques, and climate change responses, it has certainly proven to be a powerful imaginative locus (see for instance Tracey Heatherington and Bernard C. Perley, "Fieldnotes from Svalbard: How Global Dreamings Take Root in the Arctic Frontier," *Europe Now*, May 2017). Its fame has been spurred along by a highly effective communication strategy playing on the Arctic mystique and heroic narratives (routed through the documentary *Seeds of Time* and coffee-table books such as *Seeds on Ice*). As an anthropological and imaginative site, it does have its importance; but as a seed bank, it is one of the least generative and lively spaces to study. Whether it can actually be termed a seed bank at all, devoid as it is of the wider technological apparatus in which seeds can circulate, is a question I am inclined to answer in the negative.

> and set into motion for other uses through the application of technosciences […].[105]

In their account, the Frozen Ark – and, by extension, any other ex situ institution – is cast as a technological apparatus networked into a wider assemblage of scientific institutions and field practices. The lively nature of the transactions it engages in also means that the diversity of species and genetic variability it assembles is always an *experimental biodiversity*.

The experimental and networked nature of ex situ conservation also means that resistance and failure are constitutive elements of the transactions taking place in the garden and the bank. Keeping animals and plants alive, breeding, and perhaps even happy outside of their native ecosystems, or suspending the life cycles of their reproductive cells, is not by any means a frictionless process; the difficulties encountered by zoo biology in this domain, and the various revolutions made necessary by them, have been abundantly documented.[106] Seed banking and cryopreservation might be presented by their practitioners as a straightforward de-extinction practice, but both are characterised by non-replicable processes and recalcitrant subjects. As Sarah Easterby-Smith has argued, seed recalcitrance has presented considerable problems to French colonial botany from its very inception, "disrupt[ing] broad-brush assumptions about the effectiveness of a so-called 'colonial machine'" and leading to the formation of local and individualised forms of knowledge upon which the successful transport of this capricious material depended.[107] Even now, learning how to preserve recalcitrant seeds (which are less amenable to simple desiccation due to their high moisture content, among other factors) is an ongoing process of experimentation and tinkering, in which success is never guaranteed. As Fiona Hay and Robin Probert note in their survey of ex situ collecting, processing, storage, and management, wild seed banks have been engaging in intensive research to close knowledge gaps in this area. Unlike the well-oiled machine of industrial seed storage, these institutions have to contend with unknown seed longevity, variability within species, long incubation periods during germination tests, issues when breaking dormancy and germinating the stored seed. The authors note that even established

[105] Breithoff and Harrison, "From Ark to Bank," 10.
[106] See for instance Matthew Chrulew, "Managing Love and Death at the Zoo: The Biopolitics of Endangered Species Preservation," *Australian Humanities Review* 50 (May 2011).
[107] Sarah Easterby-Smith, "Recalcitrant Seeds: Material Culture and the Global History of Science*," *Past & Present* 242, no. Supplement_14 (1 November 2019): 215–42.

protocols might not always provide security, as "there have been instances where accessions stored in the [Millennium Seed Bank] have failed in a germination retest carried out using the same treatments and/or conditions that were found to be optimum at the start of storage."[108] The accidents and ignorance still woven through wild seed banking stand as a stark reminder that approaching ex situ conservation as an example of sovereignty and mastery over other species or individual nonhuman bodies risks ignoring a very productive dimension of uncertainty, recalcitrance, difficulty and ignorance.[109]

Before moving on to the emergence of transformative conservation proposals, I must distinguish them from a recent development in conservation biology I have not yet touched on: the emergence of conservation science, also called new conservation, and the ongoing "battle for the soul of conservation biology" it has sparked.[110] The ecologists Peter Kareiva and Michelle Marvier (now both affiliated with the Breakthrough Institute, an ecomodernist think-tank) published an article titled "What is Conservation Science?" in 2012 that revisited the question answered by Soulé in "What is Conservation Biology?" in 1985. Kareiva and Marvier were calling for a new framework that would go beyond conservation biology's concern with "the welfare of nonhuman nature" and improve human well-being by "managing" the environment.[111] Their proposal hinges on the "realism" of claiming "that nature can prosper so long as people see conservation as something that sustains and enriches their own lives" and practising a conservation whose "priorities include pursuing conservation within working landscapes, rebuilding public support, working with the corporate sector, and paying better attention to human rights and equity."[112] Soulé responded in a piece criticising the assumption that the trickling down of economic development would result in the protection of nature, as well

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[108] Fiona R. Hay and Robin J. Probert, "Advances in Seed Conservation of Wild Plant Species: A Review of Recent Research," *Conservation Physiology* 1, no. 1 (22 November 2013): cot030–cot030, 8.

[109] There is an interesting history of conservationist ignorance still to be written, especially when it comes to transformative projects. There have already been various applications of agnotology to environmental questions (starting with Londa Schiebinger's study of the historically fundamental role selective ignorance played in colonial-botanical transactions in *Plants and Empire*, and continuing with books such as Uekötter and Lübken's *Managing the Unknown: Essays on Environmental Ignorance*). In a sense, this is a shadow double of or an alternative red threat winding through this thesis: one of the reasons why transformative conservation projects are both marginal and generative is that ignorance is as constitutive of them as knowledge, perhaps even more so.

[110] As recounted by Keith Kloor in his report of the 2014 conference of the Western Society of Naturalists (see Kloor, "The Battle for the Soul of Conservation Science").

[111] Peter Kareiva and Michelle Marvier, "What Is Conservation Science?," *BioScience* 62, no. 11 (November 2012): 962–69, 962.

[112] Kareiva and Marvier, "What Is Conservation Science?," 968 and 962.

as Kareiva and Marvier's "shocking" dismissal of current ecological knowledge.[113] Marvier has in turn parried Soulé's criticism in another piece countering what he considers a "misrepresentation and divisive labeling of what counts as true conservation."[114] New conservation, and the conflict it has ignited among conservationists as to what exactly conservation biology ought to value and protect, is in many ways an example of what Stengers identifies when she speaks of the parasitic occupation of scientific practices by capitalism:

> In *The Invention of Modern Science* I wrote of the connivance of the so-called modern sciences with the dynamics of redefinition that singularize this delocalized, rhizomatic power known as capitalism. We can see the genial hand of capitalism in this complicity, the source of its most formidable singularity: its parasitic nature. While capitalism has destroyed many practices, it also has the ability not to destroy those it feeds on but to redefine them. So-called modern practices are affected by this parasitism, which gives them an identity that weakens any ability to resist their subjugation, pits them against one another, and leads them to condone the destruction of practices whose time has come.[115]

While it is impossible to completely disentangle the advent of new conservation from emergent transformative conservation proposals, these remain largely parallel phenomena, and I will not contend extensively with the former. The conservation projects outlined here are, for the most part, not immediately involved in the debates opposing conservation biology to conservation science, and if and when they participate in neoliberal discourse, it is by mobilising the figures of resilient, fluid, or creative agents rather than through direct appeals to the financialisation of nature. New conservation has very little to offer in terms of transformative proposals, aligned as it is with a concept of "ecosystem services" that serves to objectify rather than subjectify nature and nonhumans.

4. Transformative Conservation

[113] See Michael Soulé, "The 'New Conservation'," *Conservation Biology* 27, no. 5 (1 October 2013): 895–97.
[114] See Michelle Marvier, "New Conservation Is True Conservation," *Conservation Biology: The Journal of the Society for Conservation Biology* 28 1 (2014): 1–3.
[115] Isabelle Stengers, *Cosmopolitics I* (Minneapolis: University of Minnesota Press, 2010), 9.

In the previous section, I have endeavoured to sketch out how a genealogical approach and documentary research on contemporary conservation technologies have led me to approach ex situ conservation as a lively terrain of difficult transactions. Treating it as a field shaped by many overlapping histories of nonhuman circulation, trade, displacement and exploitation, and as a space in which the suspension and management of vital processes is never secured or finished, has trained my attention on the multiple projects that put living and banked collections into circulation. During an early interview at the Arnold Arboretum of Harvard University, an institution which functions by associating an archival effort (herbaria, gene repositories, seed banks in partner institutions) with actively curated and tended living collections on the grounds, the institution was described explicitly as an experimental one, a "petri dish" for exploring what happens where museum, living collection, research and conservation efforts overlap.[116] This is what first focused my attention on the Arboretum's involvement in assisted migration projects – a practice that will form the focus of the next chapter. Far from being only concerned with preserving local flora, the arboretum staff and researchers are attempting to ensure that it "stays at the cutting edge of plant introduction (especially in a world of rapid environmental change)," for which they "must seek out, acquire, and test untried species for growth on the grounds" – especially marginally hardy taxa with the potential to thrive in Massachusetts in changing climatic conditions.[117] Following this thread, tracking how and why conservation methods, ex situ institutions and collections are mobilised in various different projects, is what ultimately led me to what I call transformative conservation proposals.

Emerging after decades of successive recalibrations in the field of conservation biology, these practices subjectify the species or individuals they wish to protect as agents of and buffers for environmental and biological transformation. They are connected to a suite of conservation practices that include rewilding, de-extinction, cloning, novel ecosystems management or urban ecologies – in short, a range of practices that could be classified as "post-normal," or "conservation after nature," less concerned with essences than with processes, and signalling a new conservation epistemology predicated on

[116] Arnold Arboreturm Fellow, interview by author, April 10, 2017.
[117] William E Friedman et al., "Developing an Exemplary Collection: A Vision for the Next Century at the Arnold Arboretum of Harvard University" 73, no. 3 (February 2016): 4–18, 7.

relational ontologies and immanent ecological assemblages.[118] While some conservation projects "after nature" still justify their interventions by making reference to pre-existing species, places, or ecosystemic relationships, a few relatively marginal and often controversial proposals are intervening more directly in various dimensions of nonhuman life, and do so by enrolling the unpredictability of geographical, genealogical and temporal processes of these species in order to securitise a future in "post-normal" conditions. Assisted migration, assisted gene flow from crop wild relatives to crop species, and assisted evolution all emerge from the increasingly laboratised spaces of ex situ conservation as well as from the ethical and political wavering created by the neoliberal turn underway in the conservation community.

As I will unfold over the course of the next three chapters, each of these proposals has been controversial to some degree within the conservationist community. This I see as a hallmark of a vulnerability specific to any scientific practice taking place in an "unhealthy milieu." This is another term used by Stengers to characterise the parasitic operations of capitalism in contemporary scientific practices. In this milieu, scientific proposals always run the risk of recuperation, and the only path to avoiding this pitfall is, according to Stengers, to embrace science as pharmakon, and act accordingly:

> What the art of the pharmakon proposes to those who posit the diagnosis "it could be dangerous" is, by contrast, to recognize that the objection engages them, makes them an integral part of the process of fabrication. If they want to ignore that they are an integral part, they will still be so, but as judges who will contribute to a hostile or ironic milieu. On the other hand, they can also be so as allies, with questions like "how can we contribute to avoiding this danger?," "how are we to cooperate against what will be employed to confirm our diagnosis?" and "how can we participate in the creation of a milieu that will help what is venturing to exist?"[119]

The rise of transformative conservation practices sheds new light on the temptation of treating the knowledge conservation biology produces, and the power it exerts, as innocent and objective scientific practices. As long as it remains invested in the stabilising operations buttressing the ark-paradigm myth of stable suspension, conservation biology cannot properly see itself as practicing a "pharmacological art" that is potentially destructive and for which it must take political responsibility. This is not to say that the

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[118] As it has been characterised respectively in Lorimer, *Wildlife in the Anthropocene* and Neves, *Postnormal Conservation.*

[119] Stengers, *In Catastrophic Times*, 103–4.

exuberance of speculative conservation should be embraced as the breaker of dualistic chains or a turn, within a discipline long seen as stubbornly on the side of essentialism, towards fluidity and recombination. There is also danger in a fully experimental approach; simple alignment with engineering approaches are but another way of evading accountability and engagement with the fact that "it could be dangerous." Every instance of transformative conservation I will mention in this thesis is also an example of how scientists negotiate that thin line, a balancing act most notable in the literature in which they carry out the debates surrounding the proposed projects. Each of these practices is what Stengers would call insufficient – partial, grounded in a given field or concern, without any "legitimacy that transcends circumstance."[120] And this is why I attempt to excavate the material and cosmopolitical projects that haunt or weave through transformative conservation projects, and recast them as biopolitical apparatuses of knowledge production: as long as these implications remain unexamined, conservation biology risks merely aligning itself with neoliberal, ecomodernist or accelerationist agendas. The speculative openings of each of these sections are not merely fanciful thought exercises; the question I am asking is what worlds could come into being if these *singular experiments* were to be extended and transformed into *models* for what nature is, could be, or should become.[121]

The theoretical framework I will use in the following chapters is heavily indebted to a Foucauldian analysis of power/knowledge formations and subjectification processes, combined with the work of science studies scholars such as Isabelle Stengers, Bruno Latour and Donna Haraway, in particular their investigations of the ontological implications of scientific and technological practices. Foucault's analyses of biopolitics, biopower and governance have been extended past the central focus on humans, for instance by Haraway, Sara Rinfret or Timothy Nealon; a few examples of more-than-human Foucauldian scholarship are Nealon's *Plant Theory* and the edited volume *Foucault and Animals*.[122] More recently, critical studies of conservation biology have widened the remit of biopolitical concepts yet again, bringing them to bear on the

[120] Stengers, *In Catastrophic Times*, 103
[121] Stengers, *In Catastrophic Times*, 183.
[122] See *Donna Haraway, When Species Meet* (Minneapolis: University of Minnesota Press, 2007); Sara Rinfret, "Controlling Animals: Power, Foucault, and Species Management," *Society & Natural Resources* 22, no. 6 (4 June 2009): 571–78; Jeffrey T. Nealon, *Plant Theory: Biopower and Vegetable Life* (Stanford: Stanford University Press, 2015). See also Chloë Taylor, "Foucault and Critical Animal Studies: Genealogies of Agricultural Power," *Philosophy Compass* 8, no. 6 (1 June 2013): 539–51.

conservationist move to manage populations rather than individuals, on the logic of abnormality inherent to the concept of biodiversity and its preservation, the reproductive politics imposed on endangered wildlife, and various techniques for securitising life against the threat of extinction.[123]

The application of a biopolitical framework to conservation biology opens the possibility of pluralising its components and practices rather than attempting to render them all legible by applying a universal grid. A good example of this is Timothy Hodgetts' approach to mammal conservation projects: by providing a detailed analysis of two different cases (pine marten and red squirrel conservation), he shows how they participate in two different modes of biopolitics – one of them focused on techniques of security by composing liveable milieus, and the other on disciplinary policing. Subjects and objects are not made in the same way in every conservation project; political status is ascribed differentially depending on which species is being managed in which context. In a similar vein, Bierman and Anderson argue that:

> there is not a single "conservation biopolitics" but instead an entanglement of overlapping and contradictory logics and techniques. Crucially, we find that even within single domains (e.g., endangered species conservation), there exist multiple scientific understandings and associated hierarchies of value. This is significant because it underscores that conservation science is not a homogenous bloc but is itself replete with debates about which lives must be fostered and who or what is killable, and why. A biopolitical approach to conservation, therefore, contributes to a broader formulation of environmental politics, shifting the focus beyond the conventional cast of global conservation actors (e.g., NGOs, states, and development institutions) to foreground the nitty-gritty, everyday scientific assumptions, discourses, and practices that make nature governable.[124]

The possibility of granulating conservation biology into finer distinctions is useful when it comes to transformative practices that are technoscience- and engineering-adjacent. While it would be easy to read them as declensions of a single project of mastery and

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[123] See for instance Lorimer, *Wildlife in the Anthropocene*; Christine Biermann and Robert M. Anderson, "Conservation, Biopolitics, and the Governance of Life and Death," *Geography Compass* 11, no. 10 (October 2017): e12329; Christine Biermann and Becky Mansfield, "Biodiversity, Purity, and Death: Conservation Biology as Biopolitics," *Environment and Planning D: Society and Space* 32, no. 2 (April 2014): 257–73; Krithika Srinivasan, "Caring for the Collective: Biopower and Agential Subjectification in Wildlife Conservation," *Environment and Planning D: Society and Space* 32, no. 3 (1 January 2014): 501–17; and Steve Hinchliffe and Kim J. Ward, "Geographies of Folded Life: How Immunity Reframes Biosecurity," *Geoforum* 53 (1 May 2014): 136–44.

[124] Bierman and Anderson, "Conservation, Biopolitics", 2

control, they are nevertheless far more atomised, contingent and uncertain than such a reading would grasp.

In addition to this biopolitical framework, I will draw from anthropological insights into human/nonhuman relationships, such as Frédéric Keck's work on avian flu preparedness, Anna Tsing's investigation of plantation ecologies and Anthropocene proliferations, or Istvan Praet's comparative studies of indigenous and conservationist cosmologies.[125] This eclectic theoretical framework is reflective of the double movement I am aiming for in every case study chapter of this thesis: examining transformative conservation both as a power/knowledge formation, in which new forms of attention to nonhuman capabilities or uses constitutes endangered species as new kinds of subjects, and also as practices that can be studied anthropologically or cosmologically, resituated into the context of ongoing human/nonhuman transactions across histories that are cultural as well as evolutionary. Both approaches are complementary in analysing conservation proposals as instances of what Stengers calls "cosmopolitics," the constructive process of composing common worlds with heterogeneous others and radically diverging practices. The cosmopolitical gestures of conservation biology can be understood in at least two ways here. First, as the re-inscription of human interventions into nonhuman processes in a way that re-historicises the various processes by which conservationists become diplomats or insert themselves into nonhuman socialities; second, as the idea that conservation biology is itself already engaged in the creation of what could properly be termed *cosmologies*. This second gesture aims to complicate what Stephen Muecke calls the sacred, projected onto the so-called "primitive" in a modernising move that allows contemporary cultural studies and philosophy to obscure that "European forms of modernism founded a secular sacred that denied *its own* powerful ritualizations." [126] It is these ritualisations that I propose to track in the field of conservation biology, as it does not only make and unmake political subjects or objects through a suite of biopolitical interventions; it is also a framework for ordering what falls

[125] See Frédéric Keck, *Avian Reservoirs: Virus Hunters and Birdwatchers in Chinese Sentinel Posts* (Durham: Duke University Press, 2020); Anna Lowenhaupt Tsing, 'A Threat to Holocene Resurgence Is a Threat to Livability', in *The Anthropology of Sustainability Beyond Development and Progress*, ed. Mark Brightman and Jerome Lewis (New York: Palgrave Macmillan, 2017); and Istvan Praet, "Animal Conceptions in Animism and Conservation: Their Rootedness in Distinct Longue Durée Notions of Life and Death," in *Routledge Handbook of Human-Animal Studies*, ed. Garry Marvin and Susan McHugh (London, New York: Routledge, 2014).

[126] Stephen Muecke, "Cultural Science? The Ecological Critique of Modernity and the Conceptual Habitat of the Humanities," *Cultural Studies* 23, no. 3 (1 May 2009): 404–16, 409.

into the categories of life and death and for constructing an ordered space and time for humans to inhabit – or for nonhumans to trouble and exceed.

This dissertation makes use of the extensive documentary research I have conducted on the inception and transformations of conservation biology and on each of the cases that will form the focus of the next three chapters. This empirical research has taken the form of a sustained engagement with a significant amount of scientific literature (mainly peer-reviewed articles published in ecology and conservation journals, edited volumes, and conservation manuals), historical data on conservation biology, recorded presentations and interviews given by practitioners involved with the cases I was studying, documentaries, and sometimes popular science writing; I have sometimes used interviews cited in studies conducted by other scholars in the environmental humanities. In addition to this, I have conducted a series of informal and unstructured interviews between 2016 and 2020 with scientists and staff involved in ex situ conservation or the case studies examined in this thesis, including the authors of some of the seminal papers that were part of my empirical research. These were conducted either face-to-face during visits to the New York Botanical Garden, the Arnold Arboretum, the Millennium Seed Bank, the Australian PlantBank at the Royal Botanic Gardens Sydney, the Smithsonian Institution, the Royal Botanic Gardens Melbourne, and Curtin University, or remotely when such visits were not possible. These interviews do not have or aim to have the coherence of anthropological fieldwork, and I use them as a complement to the rest of my empirical research and as indicators of the tendencies in the field rather than full and comprehensive surveys of it. As such, the discussions cited in this thesis will form the basis for short vignettes scattered throughout the chapters rather than constituting a complete ethnographic body of data. They have often been the means of easing the path through the dense field of scientific literature, with my respondents acting as field guides helping me attune to unfamiliar terrain. Many of the earlier discussions, although not cited in this chapter, were instrumental in shaping my understanding of ex situ conservation as a dynamic and transformative field. Some of the later interviews were conducted late in the process and after the bulk of my documentary research had been concluded, as a means to ask follow-up questions and to evaluate the robustness of the arguments I had made on the basis of this research.

Before closing this chapter and moving on to transformative conservation proper, it seems necessary to emphasise that unlike Foucault in *The Archaeology of Knowledge*, I have investigated an open – and, of course, much narrower – field of unfinished practices and multiple alternative future histories in the making. Formulating definitive statements about what conservation biologists are doing and where they are headed is accordingly fraught, and I can only claim to trace some of the potential paths they are in the process of testing out, and to explore some of the competing epistemes and practices that are being discussed and contested, any of which might yet solidify and play a major role in shaping the discipline. A significant amount of the scientific literature cited here was published not long before or during the time I was researching this subject; the field itself was in constant mutation as I was researching it, with the first phase of the Crop Wild Relatives Project only just winding down in 2018, and new hybrid corals being replanted near the Great Barrier Reef in 2019. Still more might happen in the months that will follow the submission of this manuscript, as the nature of the field is to be fluid and in constant mutation.

Chapter 2.

"Perhaps by helping them move": Assisted Migration and Climate Change

> "So, in contrast with the power exercised on the unity of a territory, pastoral power is exercised on a multiplicity on the move."
>
> — Foucault, *Security, Territory, Population*.

I. Migration: Loss and Proliferation

1. Disturbed Mobilities

We walk on unstable ground, on a shifting Earth. Whether that movement is measured in human steps, kilometres swum upstream, or the successive waves of expanding seedlings and suckers, it is happening on compromised land. *Redistribution,* as one review of impacted routes and ecological communities under climate change calls it, is a weak word indeed to describe the upheavals visited upon ecosystems, distribution ranges, and climate envelopes.[1] And this upheaval is not metaphorical, either: what Stengers would call the "intrusion" of Gaia – another name for an "assemblage of material processes" that is not quite the Earth, not quite the climate, not quite Lovelock and Margulis' living planetary organism[2] – is reshuffling movement, that particular form of liveability and inhabitability. Vast swaths of the planet, under the mounting pressure of climate change and habitat fragmentation, have been made into what Rose has called "wounded space," a world made "wild," apparently paradoxically, by the severing operations of colonial ecocide.[3] In this destructive wildness, the movements of a

[1] See Gretta T. Pecl et al., "Biodiversity Redistribution under Climate Change: Impacts on Ecosystems and Human Well-Being," *Science* 355, no. 6332 (31 March 2017): eaai9214.

[2] Stengers, *In Catastrophic Times*, 48.

[3] Deborah Bird Rose, *Reports from a Wild Country: Ethics for Decolonisation* (Sydney: University of New South Wales Press, 2004), 34. Earlier in the book, Rose mentions that in a discussion with one of her informants, "Daly went on to speak of quiet country – the country in which all the care of generations of people is evident to those who know how to see it. Quiet country stands in contrast to the wild; we were looking at wilderness, man-made and cattle-made. This "wild" was a place where the life of the country was falling down the gullies and washing away with the drains." (4). This important distinction between *quiet* and *wild* country is one that is foundational to understanding the tensions

staggering number of species are becoming severely compromised, and with them the various forms of world- and kin-making enabled by nonhuman mobilities.

Just like the compromised Earth ecologies it seeks to understand and respond to, the contemporary discourse on faunal and floral migration in a time of climate change is conflicted and in flux. In his book on the decline in animal migrations over the last two centuries, David Wilcove writes that:

> Simply stated, the phenomenon of migration is disappearing around the world. […] Migratory animals have weathered plenty of changes over the years, up to and including such dramatic events as the retreat of the Pleistocene ice sheets less than twelve thousand years ago. But the pace of change seems so much quicker today than in the past, leaving scientists to wonder which species will be able to cope and which will not.[4]

This conclusion is echoed by many other biologists studying the effects of climate change on plant and animal mobility. But migration is not only disappearing; it is, rather, becoming unevenly distributed and facilitated:

> Changes in species composition can take two paths, via in situ conversion, that is, subdominant species replacing dominant ones, or via migration of species from other locales. In situ conversion is likely to begin before new migrants can attain a significant functional role. Yet, if the climate changes rapidly, and especially if climate change is accompanied by widespread disturbance, some species and their functions may be lost before those functions can be replaced by either dominance shifts or new migrants. […] Ecosystem simulations under future climate scenarios suggest that the preferred ranges of many species could shift tens to hundreds of kilometers over only 50 to 100 years, nearly an order of magnitude faster than may have occurred since the last glaciation […]. Species that cannot migrate at sufficient rates to track climate change might go extinct, possibly reducing the adaptability of those ecosystems to climate change.[5]

This is where we arrive at the tension at the heart of movement ecology: while the planet is losing forms and pathways of migration, it has also become the stage of a teeming, riotous, often dangerous proliferation of unchecked movement across all taxa

animating assisted migration. I will return to it later in this chapter, and work through several other similar oppositions in order to untangle some of the unspoken conflations between indigenous care and other forms of assisted movement that breed in contemporary assisted migration discourse.

[4] David S. Wilcove, *No Way Home: The Decline of the World's Great Animal Migrations* (Washington: Island Press, 2008), 5-7.

[5] Ronald P. Neilson et al., "Forecasting Regional to Global Plant Migration in Response to Climate Change," *BioScience* 55, no. 9 (1 September 2005): 749–59, 750.

and kingdoms. Colonialism has accelerated wildlife movements by a variety of means, such as the deliberate introduction of cattle and crops by settlers, the unintentional introduction of invasive organisms in the wake of colonial expeditions, the trade of ornamental plants and "exotic" animals that was started to satisfy imperial appetites for novelty and is still underway today, and the illegal trafficking of a variety of beings for aesthetic, medicinal or entertainment purposes.[6] As of the writing of this thesis, the world has been swept by several waves of the COVID-19 pandemic; a harsh and timely illustration of the mechanisms enabling what Tsing, Mathews and Bubandt call the "feral proliferations" of the Anthropocene. These proliferations – the unchecked and destructive movements of those pests, pathogens and weeds that become newly destructive through global circulation – are one of the ways in which modernity and colonialism have accelerated wildlife movement, along with introductions, acclimatisation, trade, and trafficking. They are the results of "modular simplifications," which have presided over the creation of standardised or clone-populated plantations and industrial feedlots. Standardised landscapes are vulnerable landscapes, offering no asperities or complexities that could stop the spread of opportunistic organisms.[7] Nonhuman migration is one of the ecological processes disturbed by this conjunction of ecological density and simplification, and it is marked by proliferation as well as loss through fragmentation and asynchronicity. The literature on the subject describes prodigious upheavals, spanning continents and ecosystems:

> For marine, freshwater, and terrestrial species alike, the first response to changing climate is often a shift in location, to stay within preferred environmental conditions. At the cooler extremes of their distributions, species are moving poleward, whereas range limits are contracting at the warmer range edge, where temperatures are no longer tolerable. On land, species are also moving to cooler, higher elevations; in the ocean, they are moving to colder water at greater depths. Because different species respond at different rates and to varying degrees, key interactions among species are often disrupted, and new interactions develop. These idiosyncrasies can result in novel biotic communities and rapid changes in ecosystem functioning, with

[6] For an overview of the biological effects of European colonialism, see Alfred E. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900-1900* (Cambridge: Cambridge University Press, 1986). For an example of contemporary animal trafficking, see David Jaclin, 'In the (Bleary) Eye of the Tiger: An Anthropological Journey into Jungle Backyards," *Social Science Information* 52, no. 2 (June 2013): 257–71.

[7] Anna Lowenhaupt Tsing, Andrew S. Mathews, and Nils Bubandt, "Patchy Anthropocene: Landscape Structure, Multispecies History, and the Retooling of Anthropology: An Introduction to Supplement 20," *Current Anthropology* 60, no. S20 (August 2019): S186–97, S187.

> pervasive and sometimes unexpected consequences that propagate through and affect both biological and human communities.[8]

The current paradox, then, is this: plants, animals, fungi and micro-organisms are moving too much *and* too little at the same time. In other words, and according to a paper on the ongoing amphibian fungal panzootic, the increasingly dense vectors of human mobility have "recreated a functional Pangaea for infectious diseases in wildlife, with far-reaching impacts on biodiversity, livestock, and human health."[9] As we will see at the end of this chapter, these kinds of deep time allusions abound in the discourse surrounding nonhuman movements, surfacing in various declensions of care and violence, as cautionary tales or justification narratives; here, Pangaea designates an unsettling and destructive return to a geophysical configuration current ecosystems are not ready to adapt to. It might be dynamic and teeming with movement, but it is also a cognate of Stengers' Gaia, who is in the process of shrugging off humans and other living beings now that her "margin of tolerance has been well and truly exceeded," whose intrusion is blind to the mass extinction event it causes.[10]

The anthropogenic disturbances that have come to bear on both ecosystems and climate have the effect of simultaneously hindering the movements that are the product of long co-evolutionary histories and intraspecific cultural transmissions and of facilitating the most opportunistic migrations, usually those of organisms classified either as weeds or pathogens. While nomads depending on relatively stable and navigable pathways and on the ability to cross treacherous terrain on their own may suffer, more flexible migrants who are able to hitchhike on the new pathways created by human industry and divert them to their own purposes are proliferating more dangerously than ever. This unchecked circulation might also be playing a part in homogenising biodiversity worldwide, a process that has prompted some biologists to forecast the emergence of a "Homogocene" and to draw parallels with "the now global loss of regional languages, the widespread distribution of fast-food restaurants and the rapid replacement of local businesses by multi-national retailers."[11] As I will show in this chapter, the question of

[8] Pecl et al., "Biodiversity redistribution," 1.

[9] Ben C. Scheele et al., 'Amphibian Fungal Panzootic Causes Catastrophic and Ongoing Loss of Biodiversity', *Science* 363, no. 6434 (29 March 2019): 1459–63, 3.

[10] Stengers, *In Catastrophic Times*, 46.

[11] Julian D. Olden, Lise Comte, and Xingli Giam, "The Homogocene: A Research Prospectus for the Study of Biotic Homogenisation," *NeoBiota* 37 (6 March 2018): 23–36, 31.

whether biotic homogenisation is quite as frictionless as this comparison makes it seem is complicated by the resistances nonhumans can offer to the plans of capitalism and conservation both.

The somewhat contradictory studies I open this chapter with illustrate what happens in *wild country*, places and spaces in which species and individuals have been made fungible through processes of industrial simplification and imperial projects. Assisted migration, the first example of transformative conservation examined in this thesis, is a practice that has the potential to address, question, or prolong that wildness, and as such it inherits the tensions and burdens that characterise manufactured ecological patchiness.

2. Assisting Migration

As Jessica Hellmann, an ecologist and director of the Institute on the Environment at the University of Minnesota, tells me during an interview, the stated goal of assisted migration is to preserve diversity against the eroding effects of biotic homogenisation.[12] The flows connecting our New Pangaea, it seems, could be harnessed to mitigate the very harm they threaten to inflict: allowing less mobile species to catch up to the rhythms of seasoned travellers is one solution put forward by conservation biologists to ensure the variety, vitality and robustness of populations. They contend that survival of a species and of species richness can no longer be guaranteed by the safeguarding of a recognisable, bounded territory in which these species thrive. In a shift parallel to the transformations of power formations diagnosed by Michel Foucault in his writing on governmentality and biopolitics, from sovereign territorial concerns to securitising populations, conservation biology is shifting its focus to a "multiplicity on the move."[13]

Intervening in the movement and distribution of endangered wild species has become an increasingly prominent task for conservation and restoration practices. As the first chapter laid out, conservation biologists have been reckoning with the problem of connectivity for the last fifty years, discussing whether natural reserves are well-connected enough to have any measurable impact on wildlife preservation. Beyond the debate on SLOSS and corridors that animated conservation biology in the 1980s,

[12] Jessica Hellmann, interview by author, June 8, 2020.
[13] Foucault, *Security, Territory, Population*, 171.

ecological restoration has also become the site of interventions such as rewilding, reintroduction, and translocation. Richard Corlett, a biologist working at the Xishuangbanna Tropical Botanical Garden, proposes a taxonomy of twenty restoration, reintroduction and rewilding terms in which assisted migration appears as a subcategory of conservation introductions outside of the native range.[14] While assisted migration certainly fits into a wider set of interventionist practices which, according to Corlett, "came into common use during the nostalgic phase of conservation biology, when the initial, preservationist phase was running out of pristine areas to protect and the main task facing conservationists was seen as returning degraded ecosystems to their previous state, or as close to this as possible," it also marks a significant break with other forms of restoration ecology.[15] Corlett's taxonomic efforts are representative of resurging anxieties about the hollowing out of conservation practices by shifting baselines, which makes any reference to historical states for restoration purposes difficult if not impossible, and assisted migration – along with adjacent literature on novel ecosystems that I will discuss in more detail in the next section – is the proposal most explicit in its embrace of this "trouble."[16] Ricciardi and Simberloff, who stand prominently on the side of those concerned with the implications of assisted migration, see the rise of assisted migration as evidence of "the emergence among some conservationists of a new philosophy regarding species introductions that is at odds with the traditional objective of preservation."[17] They suggest that assisted migration proposals are the understandably appealing but scientifically misguided result of accelerating ecological crises and of the conflict between rigorous assessments and the need for immediate action felt by many conservation biologists.

This is how matters stand now, broadly speaking. But when and how did this new matter of concern – this new issue around which conservation biologists gather and which they invest with the power to make them think and experiment with circulatory processes – emerge among conservationists?[18]

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[14] Richard T. Corlett, "Restoration, Reintroduction, and Rewilding in a Changing World," *Trends in Ecology & Evolution* 31, no. 6 (June 2016): 453–62, 454.

[15] Corlett, "Restoration, Reintroduction, and Rewilding," 453.

[16] I borrow the term from Haraway, *Staying with the Trouble*.

[17] Anthony Ricciardi and Daniel Simberloff, "Assisted Colonization Is Not a Viable Conservation Strategy," *Trends in Ecology & Evolution* 24, no. 5 (1 May 2009): 248–53, 248.

[18] This definition of matters of concerns is taken from Stengers ("Matters of Concern All the Way Down," *Ctrl-Z: New Media Philosophy*, no. 7 (2017)), and her rerouting of Latour's negotiations with right-wing co-opting of critique and his call to move from "matters of fact" to "matters of concern" – that is,

The idea took shape in an article published in 1985 by Joan Darling and Robert Peters, in which the authors discuss it in the context of wildlife reserves and their future in a world repatterned by catastrophic climate change. Darling and Peters discuss management options for wildlife reserves, suggesting, among other things, that when "old reserves do not retain necessary thermal or moisture characteristics, individuals of disappearing species may have to be transferred to new reserves. For example, warmth-adapted ecotypes or subspecies may have to be transplanted to reserves nearer the poles."[19] This article exemplifies the blurring boundaries between the two environmental power formations bridged by the emergence of transformative conservation proposals: Darling and Peters are still operating with a territorial conception of governance, where the threat of unravelling structures and climates can be mitigated by a transplantation of tightly managed and geographically bounded reserve micro-territories, displacing the exercise of sovereign power without questioning it.

The full significance of assisted migration for shifting environmental governance would not be realised until about two decades later. The coining of the term itself is often attributed to Brian Keel, who introduced the term in his doctoral dissertation on *Habenaria repens* orchid conservation.[20] The research he was undertaking as a graduate student at the time coincided with the growing visibility of another project, the volunteer-led and controversial Torreya Guardians project, which sought to transplant an endangered conifer across US state borders by cultivating it on private land.[21] Its founder, the science writer (and self-proclaimed "evolutionary evangelist") Connie Barlow, co-authored the first public appeal to consider assisted migration with the palaeoecologist Paul Martin. The article, which appeared in the 2004 forum of the journal *Wild Earth*, claims that moving *Torreya taxifolia*, the "world's most endangered conifer," from Florida to Appalachia is "easy, legal, and cheap." The article also makes the case that plants in

asking what facts are capable of rather than debunking their veracity (see Bruno Latour, "Why Has Critique Run out of Steam?: From Matters of Fact to Matters of Concern," *Critical Inquiry* 30, no. 2 (1 January 2004): 225–48).

[19] Robert L. Peters and Joan D. S. Darling, "The Greenhouse Effect and Nature Reserves: Global Warming Would Diminish Biological Diversity by Causing Extinctions among Reserve Species," *BioScience* 35, no. 11 (1 December 1985): 707–17, 715.

[20] His dissertation, "Assisted Migration as a Conservation Strategy for Rapid Climate Change: Investigating Extended Photoperiod and Mycobiont Distributions for Habenaria repens Nuttall (Orchidaceae) as a Case Study," was submitted in 2007. See also Brian Keel, "Climate Change and Assisted Migration of At-Risk Orchids," *Selbyana* 26, no. 1/2 (2005): 355–355.

[21] See Patrick D. Shirey et al., "Commercial Trade of Federally Listed Threatened and Endangered Plants in the United States," *Conservation Letters* 6, no. 5 (1 September 2013): 300–316.

general are particularly good guerrilla partners because they can be relocated "with no governmental oversight or prohibitions," as opposed to the costly and difficult translocations of endangered animals – a view that would (and does) raise a considerable number of hackles among conservation biologists.[22]

While the Torreya Guardians have been and still are used as a rhetorical foil for more reputable proposals in the literature on assisted migration, the existence of this group churned up concerns that were clearly shared across a wider section of the conservation community. In 2007, Mark Schwartz, Jessica Hellmann and Jason McLachlan published a "framework for debate on assisted migration," arguing that waiting for better data on a contentious issue such as this one was impossible, and that biologists should start considering scientifically based policies for species translocation.[23] Since then, as Ricciardi and Simberloff have bemoaned, the attention and credibility lent to this proposal has only increased, making it one of the most extensively debated issues in transformative conservation, a contested locus of arguments that transcend questions of feasibility, and of disputes in which the definition of conservation biology itself is sometimes at stake.

It is useful to return to Latour's analysis of how scientific networks are built when engaging with the current status of assisted migration. In the preceding chapter, I established the impossibility of studying conservation biology in a cold, stabilised state. Assisted migration is a clear example of a set of statements that have not yet been conclusively established or disproven by a robust set of retorts, debates and counterarguments.[24] In fact, a sizeable amount of the literature on the subject is concerned with anxious deliberations about terminological accuracy. One paper, for instance, states that:

> Two issues plague the debate on assisted migration: *terminological plurality* and *definitional varieties*. Terminological plurality means that besides "assisted migration," many other terms have been employed. The most common ones are "assisted colonization" […] and "managed relocation," but a quick literature review reveals "facilitated migration," "assisted range

[22] Connie Barlow and Paul S. Martin, "Bring Torreya Taxifolia North – Now," *Wild Earth*, 2004, 53.
[23] See Jason S. McLachlan, Jessica J. Hellmann, and Mark W. Schwartz, "A Framework for Debate of Assisted Migration in an Era of Climate Change," *Conservation Biology: The Journal of the Society for Conservation Biology* 21, no. 2 (April 2007): 297–302.
[24] Latour, *Science in Action*, 27.

> expansion" and a plethora of other phrases. […] Definitional varieties refer to the abundance of proposed definitions that differ from each other.[25]

As can be expected from "warm" research in the making, the shifting and proliferating terminology used by conservation biologists to either buttress or discredit this proposal has cycled through terms such as assisted colonisation (sometimes distinguished from assisted migration as the "movement of species far outside their range for conservation purposes"[26]), assisted migration, managed relocation or chaperoned relocation.[27] It has been defined as the "translocation of a species to favourable habitat beyond their native range to protect them from human induced threats, such as climate change" or, alternatively and in a more nuanced language, "the purposeful movement of species to facilitate or mimic natural range expansion, as a direct management response to climate change."[28] One recent publication by several Finnish biologists has attempted a more finely granulated definition by examining "the general idea of *moving organisms in response to climate change* and distinguish[ing] from it the more specific idea of *aiding the dispersal of species threatened by climate change*"; the latter is what they ultimately settle on calling assisted migration (arguing that it is not synonymous with but a subcategory of assisted colonisation), defining it as follows:

> Assisted migration means safeguarding biological diversity through the translocation of representatives of a species or population harmed by climate change to an area outside the indigenous range of that unit where it would be predicted to move as climate changes, were it not for anthropogenic dispersal barriers or lack of time.[29]

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[25] Marko Ahteensuu and Susanna Lehvävirta, "Assisted Migration, Risks and Scientific Uncertainty, and Ethics: A Comment on Albrecht et al.'s Review Paper," *Journal of Agricultural and Environmental Ethics* 27, no. 3 (1 June 2014): 471–77, 471.

[26] Laura Gray et al., "Assisted Migration to Address Climate Change: Recommendations for Aspen Reforestation in Western Canada," *Ecological Applications* 21 (1 July 2011): 1591–1603, 1591.

[27] See respectively Cathy Whitlock and Sarah H. Millspaugh, "A Paleoecologic Perspective on Past Plant Invasions in Yellowstone," *Western North American Naturalist* 61, no. 3 (2001): 316–327, David M. Richardson et al., "Multidimensional Evaluation of Managed Relocation," *Proceedings of the National Academy of Sciences* 106, no. 24 (16 June 2009): 9721, and Adam B. Smith, Matthew A. Albrecht, and Abby Hirdi, "'Chaperoned' Managed Relocation," *BGjournal* 11, no. 2 (2014): 19–22.

[28] Respectively in Ricciardi and Simberloff, "Assisted Colonization," 248 and Pati Vitt et al., "Assisted Migration of Plants: Changes in Latitudes, Changes in Attitudes," *Biological Conservation* 143 (31 January 2010): 18–27, 19.

[29] Maria H. Hällfors et al., "Coming to Terms with the Concept of Moving Species Threatened by Climate Change – A Systematic Review of the Terminology and Definitions," *PLOS ONE* 9, no. 7 (23 July 2014): e102979, 10.

This purposeful relocation of species would mitigate both the effects of habitat fragmentation – mimicking plant dispersal along naturally occurring corridors, for example – and those of climate change, helping species migrate faster to keep up with their natural range's shifts in the coming years and decades.

The lack of solidly implemented or scalable assisted migration projects is symptomatic both of the novelty of the proposal (which poses epistemological problems) and of a shift in the very object of conservation biology as a whole (a shift that plays out on an ontological level). While the Torreya Guardians volunteers have been privately replanting the conifer for years, publicly funded studies are still few and far between. One test-study, conducted in the UK in 2009, saw two species of butterflies translocated to neighbouring sites projected to become more climatically favourable; the success of the populations in their new range led the authors of the study to conclude that there had indeed been a migration lag, and to "suggest that assisted colonization may be a feasible and cost-effective means of enabling certain species to track climatic change."[30] More recently, from 2013 to 2015, the University of Helsinki, the Finnish Environment Institute, and the universities of Oulu, Turku and Tartu implemented the Assisted Migration in Climate Change Adaptation: Opportunities and Constraints (CO-ADAPT) project. It consisted of growing several plant species (*Primula nutans*, *Oxytropis campestris ssp. sordida* and *Astragalus alpinus ssp. Arcticus* first, joined by *Oxytropis campestris* ssp. *sordida* and *Astragalus alpinus* ssp. *Arcticus* in 2015) in experimental plots set up at botanic gardens in Finland, Norway and Estonia, in order to measure how they are impacted by climate change and whether it will threaten their future survival.

3. Insufficient Practices

Most articles on assisted migration offer recommendations (for seed collecting or actual translocations), feasibility studies, ethical frameworks, terminological reviews and clarifications, theoretical contributions to the ongoing debate or desiderata for future accessions.[31] As a very new, "warm" scientific proposal in the making, it is engaged in

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[30] Stephen G. Willis et al., "Assisted Colonization in a Changing Climate: A Test-Study Using Two U.K. Butterflies," *Conservation Letters* 2, no. 1 (1 February 2009): 46–52, 45.

[31] On seed collecting, see Edward O. Guerrant, Kayri Havens, and Pati Vitt, "Sampling for Effective Ex Situ Plant Conservation," *International Journal of Plant Sciences* 175, no. 1 (1 January 2014): 11–20, and Kayri Havens et al., "Seed Sourcing for Restoration in an Era of Climate Change," *Natural Areas Journal* 35, no. 1 (1 January 2015): 122–33. For feasibility studies see Gray et al., "Assisted migration to

exactly the dense tangle of rhetoric and citational practices described by Latour in *Science in Action*. The past few years have seen a flurry of articles responding to and contradicting each other, some of them engaged in direct dialogue, proposing everything from unified ethical frameworks to methods for efficient seed sampling and examinations of species invasiveness, and the debate is still ongoing.[32]

As these intense debates - waged via letters and responses - have shown, assisted migration is the locus of intersecting anxieties. Of the three case studies driving each of this thesis' main sections, assisted migration might arguably stand as the one perceived as riskiest. As we will see later, the Crop Wild Relatives Project and coral assisted evolution both differ markedly from assisted migration in terms of scope. While they are both interventionist and debated practices, they still purport to either leave wild plants untouched (an assumption I will complicate in my discussion of the Crop Wild Relatives Project) or to enable a handful of coral species to adapt better to changing conditions without necessarily questioning the composition of the ecosystem they support (a question that will also be unfolded further in my analysis of experimental hybridisation). In 2008, during the early days of the assisted migration debate, the writer Emma Maris described it as "breaking a conservation taboo,"[33] and it certainly has generated more

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address climate change" and as well as Maria H. Hällfors, Sami A. Aikio, and Leif E. Schulman, "Quantifying the Need and Potential of Assisted Migration," *Biological Conservation* 205 (1 January 2017): 34–4. On ethical frameworks, see Mark W. Schwartz et al., "Managed Relocation: Integrating the Scientific, Regulatory, and Ethical Challenges," *BioScience* 62, no. 8 (1 August 2012): 732–43. On terminological issues, see Hällfors et al., "Coming to Terms." On theoretical contributions to the broader assisted migration debate, see Maria Hällfors, Elina Vaara, and Susanna Lehvävirta, "The Assisted Migration Debate – Botanic Gardens to the Rescue?," *BGjournal* 9, no. 1 (2012): 21–24. On desiderata for future botanic garden accessions, see Friedmann et al., "Developing an Exemplary Collection."

32 Some journals have been the stage for an interplay of response and citation between articles and letters: Ricciardi and Simberloff's "Assisted Colonization," in which the authors assert that "much of the literature on assisted colonization pays little attention to the importance of evolutionary context in conservation biology and places too much faith in risk assessment," has been responded to by Pati Vitt, Kayri Havens, and Ove Hoegh-Guldberg, "Assisted Migration: Part of an Integrated Conservation Strategy," *Trends in Ecology & Evolution* 24, no. 9 (September 2009): 473–74. Another such set of tightly interlinked articles is formed by Ove Hoegh-Guldberg et al., "Assisted Colonization and Rapid Climate Change," *Science* 321, no. 5887 (18 July 2008): 345, Chris D. Thomas, "Translocation of Species, Climate Change, and the End of Trying to Recreate Past Ecological Communities," *Trends in Ecology & Evolution* 26, no. 5 (May 2011): 216–21, Bruce L. Webber, John K. Scott, and Raphael K. Didham, "Translocation or Bust!: A New Acclimatization Agenda for the 21st Century?," *Trends in Ecology & Evolution* 26, no. 10 (October 2011): 495–96; author reply 497-498, and Montserrat Vilà and Philip E. Hulme, "Jurassic Park? No Thanks," *Trends in Ecology & Evolution* 26, no. 10 (October 2011): 496–97.

33 Emma Marris, "Moving on Assisted Migration," *Nature Climate Change* 1, no. 809 (1 September 2008): 112–13.

stringent debates and raised more ethical issues than other, arguably more technically and experimentally advanced transformative conservation practices.[34]

As I mentioned in the previous chapter, Stengers trenchantly reminds us that the "catastrophic times" of Gaian intrusion are those in which the categories of remedy and poison, of the catastrophe and the after-catastrophe, of struggle and creation all undergo redistributions which fundamentally destabilise any sciences that could or would still think of themselves as innocent:

> the time of guarantees is over – that is the first meaning to confer on the intrusion of Gaia. This does not signify that anything goes [...]. It does signify that what is valuable must in the first place be defined as vulnerable. By definition the dynamics of the creation of knowledges, of struggles, and of experiments that will respond to the intrusion – each insufficient by itself but important through its possible connections and repercussions – will be vulnerable.[35]

This vulnerability is particularly marked in assisted migration projects. It ventures into what the scientists who have made themselves spokespersons for assisted migration should know to be an "unhealthy milieu," one in which their practices can always be recuperated by the various other protagonists that scientists involve themselves with (corporations, governments, and so forth) – opening up to technological interventions some biologists have uneasily alluded to as "Jurassic Park."[36] This danger, and the insufficient, partial, and situated practices that could stave it off, are at the heart of the assisted migration debate.

The emergence of assisted migration as a contentious but increasingly credible proposal is symptomatic of emerging reconfigurations in conservation biology, as it confronts and seeks to intervene in new forms of complexity and contingency. The discourse carried by those scientists in favour of assisted migration reveals that their understanding of the object of conservationist care and practice has shifted from stable entities in bounded territories to fluid assemblages and dynamic evolutionary actors. Reading this reconfiguration through the lens of a Foucauldian analysis of

[34] As we will see in the next two chapters, while the Crop Wild Relatives Project is still in its pre-breeding infancy, it has led to well-funded and robust collecting efforts. The assisted evolution of corals is a marginal project but effectively in progress at the Australian Institute for Marine Science, among other locations.

[35] Stengers, *In Catastrophic Times*, 103.

[36] See Vilà and Hulme, "Jurassic Park? No thanks."

governmentality is useful for understanding how conservation institutions are involved in epistemological and disciplinary operations that make nature governable in new or recombinant ways. In this chapter, assisted migration will serve as a first exploration of the epistemological, historico-political and ontological shifts that have reconfigured conservation biology since its formal consolidation into a discipline – shifts that are not legible when conservation biology is approached with the assumption that it is still largely based on static and essentialist ontologies. Assisted migration is a conservation proposal that both reveals and drives the conservationist turn to ontological indeterminacy, incalculable contingency, and neoliberal governmentality; it is representative of an alignment, in conservation biology, with forms of governance whose object is circulation and its regulation. I argue that this shift is particularly legible in the way assisted migration transforms the meaning, use, and function of ex situ collections, forcing scientists to re-evaluate how they understand and constitute available stores of captively held and bred endangered species. From there I will develop an analysis of the new form of conservationist governance that makes the emergence of migratory concerns possible and pressing, and which fully integrates radical contingency and processes of ontological becoming as reorganising elements of any future environmental episteme. On this basis, I will go on to analyse how assisted migration is situated at the confluence of, on the one hand, assumptions about unstable ground, dynamic natures and impossible securitisation, and, on the other, of an investment in horticultural expertise and plantation thinking,[37] and delineate one of the possible speculative futures rehearsed in these transformative proposals. While these futures can be presented, by some proponents of assisted migration, as frictionless enough to speed along linear vectors of growth and expansion, it is worth bearing in mind Stengers' definition of scientific experiment – of which assisted migration is a hybrid and perhaps novel example.[38] Experiments, and more specifically *good* experiments, are the ones in which the very phenomena and

[37] An argument prominently informed by Tsing's writing on the Plantationocene; see Donna Haraway, "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin", *Environmental Humanities* 6, no. 1 (2015): 159–65.

[38] "In order to think sciences as an adventure, it is crucial to emphasize the radical difference between a scientific conquering 'view of the world' and the very special and demanding character of what I would call scientific 'achievements.' In experimental sciences, such achievements are the very condition of what is then, after they have been verified, celebrated as an objective definition. An experimental achievement may be characterized as the creation of a situation enabling what the scientists question to put their questions at risk, to make the difference between relevant questions and unilaterally imposed ones." (Isabelle Stengers, "Reclaiming Animism," *e-flux*, July 2012.)

subject mobilised in the experimental setting have the power to redefine the questions asked by the experimenters. As I argued in the first chapter of this thesis, a topological approach to the dynamic landscape of conservation biology is useful for understanding the "plurality of trajectories"[39] made possible by the emergence of every new transformative proposal. And while scalable dreams and plantation thinking are one of the potential outcomes of assisted migration proposals, there is also space for the emergence of another discourse, characterised by references to and reliance on deep time and intertwined human and nonhuman histories. This, I argue, is another speculative line constituted by assisted migration proposals, and might well destabilise the very question being asked in the debates surrounding them.

[39] Deleuze, *Essays Critical and Clinical*, 67.

II. Reconfiguring Practices

1. Ex Situ Ground

Before moving on to concrete assisted migration proposals and test-studies, I will make a detour through the changing fortunes of seed collection in conservation and restoration ecology. As I noted in the first chapter, while the case studies presented in this thesis all transcend the spaces of ex situ conservation proper, their emergence is predicated in part on the possibility, opened in and by these institutions, of paying attention to a variety of nonhuman capabilities. They might otherwise be overshadowed in the field, either because environmental and temporal constraints lead to them being overlooked, or because plants and animals have not yet been brought into relations that would reveal different abilities and make them the focus of conservationist concern. Ex situ, the bodies or gametes of endangered wild species are simultaneously suspended and subjected to intensive circulation, crossing and recrossing institutional boundaries and brought into interspecies assemblages that could not have formed in situ. This circulation, in turn, problematises the structures in which it takes place, sometimes by revealing that they operate on theoretical assumptions that are of little use when put to the test. Contemporary social studies of science have problematised the circulatory nature of conservation institutions and the epistemological and ontological effects of connecting different heterotopias such as botanical gardens, zoos, medical laboratories, and freezers. Carrie Friese has examined how the intersection of reproductive technologies with zoological captive breeding techniques, for the purpose of cloning endangered animals, transforms both zoos and the kinds of nature it reproduces through science and technology. As she puts it, "cloning endangered animals within zoos is a site where ideas about species preservation are being reworked."[40] Friese argues that it is important to study cloning practices in their context rather than assuming that cloning is a unified and deterministic biotechnology. Articulating laboratory practices and zoo biology in different spaces, for different species and in different configurations brings forth categories of animals differentiated by Friese in her effort to characterise the micro- and meso-level

[40] Friese, *Cloning Wild Life*, 4.

practices of wildlife cloning. In the same vein, Breithoff and Harrison have proposed a reading of the Frozen Ark, a UK-based project banking the DNA of endangered wild animals, as the locus of new articulations between field and freezer. This shift endows the Frozen Ark and other biobanks with "a more active function which acknowledges their potential for reanimation of genetic material in future de-extinction programmes," [41] a role which allows them to mobilise a complex set of relationships between heterogeneous institutions and field sites.

Assisted migration similarly rearticulates relations between field, seed collections, and restoration practices, as the pitfalls of implementing this (as of yet largely speculative) proposal force scientists to contend with their own assumptions concerning the constitution, management and use of their seed accessions. This is due in large part to the fact that many of the proposals I touch on in this chapter have explicit institutional links with botanic gardens and ex situ collections. Hällfors et al., for instance, argue that "although on its own [ex situ conservation] is not a sustainable solution for conservation, it does provide an essential step in the process of introducing species back to the wild" – a process that includes moving them to novel ranges.[42] The CO-ADAPT project Hällfors worked on as a postdoctoral researcher, with its experimental plots set up in botanic gardens in Finland, Norway and Estonia, was a direct application of this principle. In a similar move toward experimental trials, scientists at the Arnold Arboretum of Harvard University have proposed the collection and cultivation of "marginally hardy taxa," which might prove to be more suited to the climate in Massachusetts in the coming decades than the species now living there.[43] Other biologists and botanists affiliated with botanic gardens have weighed in on assisted migration, for instance a group of researchers at the Missouri Botanic Garden calling for "chaperoned assisted migration, in which botanic gardens serve as waypoints for transferred species."[44] Their discussion of how to best curate wild-specimen collections so as to avoid unwanted hybridisation echoes the

[41] Breithoff and Harrison, "From Ark to Bank," 2.
[42] Hällfors et al., "The Assisted Migration Debate," 22.
[43] "In the spirit of exploration and experimentation, the Arboretum has continually acquired germplasm of marginally hardy taxa to be coaxed into cultivation, despite and against all odds. To ensure that the Arboretum stays at the cutting edge of plant introduction (especially in a world of rapid environmental change), it must seek out, acquire, and test untried species for growth on the grounds. Importantly, identification of new 'marginal' taxa should be coupled with targeted field collections of germplasm from parts of the taxon's natural range that are likely to predispose such accessions to ultimate success on the grounds." (Friedman et al. "Developing an Exemplary Collection," 7)
[44] Smith et al., "'Chaperoned' Managed Relocation," 20.

collections challenges that Kayri Havens and Pati Vitt, who both work at the Chicago Botanic Garden, have grappled with.[45] I argue in this chapter that botanic gardens have emerged as a privileged site for testing assisted migration proposals, debating the promises and perils of such proposals, and catalysing shifts in how conservation biology knows, stores and classifies its material.

2. Collection Matters

I have been using the term conservation biology, so far, as a wide umbrella for the case studies investigated here. Assisted migration, however, might be classified more properly as a restoration practice. While it is aligned with conservation biology in its focus on single-species preservation and on halting their extinction, it also intervenes into degraded habitats in a manner similar to restoration projects, whose "objective is to restore the functioning ecosystems that existed before degradation, although the species composition may differ substantially from what was there before."[46] It could, in fact, be described as an offshoot of what Truman P. Young sees as conservation research conducted with a "restoration mind set":

> In fact, several major activities of conservation biologists are fully in the restoration mind set. Reintroduction projects and research are about single species restorations, although rarely coupled with an overall community restoration project. Although limited in species richness, captive breeding and gene bank programs often have as one of their main assumptions the future restoration of functional ecosystems.[47]

The assumption that banked biological material is ultimately destined to be reintroduced is what opens the door to unorthodox and ambiguous restoration practices such as assisted migration. Restoration ecologists are already facing the issues that come with reintroducing species into ecosystems transformed by climate change; assisted migration brings these issues to bear on ex situ institutions and practices, and in so doing

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[45] See Guerrant, Havens and Vitt, "Sampling for Effective Ex Situ Plant Conservation" and Havens et al., "Seed Sourcing for Restoration."

[46] John A. Wiens and Richard J. Hobbs, "Integrating Conservation and Restoration in a Changing World," *BioScience* 65, no. 3 (1 March 2015): 302–12, 304. For assisted migration as a subcategory of restoration and reintroduction, see Corlett, "Restoration, Reintroduction, and Rewilding."

[47] Truman P. Young, "Restoration Ecology and Conservation Biology," *Biological Conservation* 92, no. 1 (1 January 2000): 73–83, 79.

problematises the limited and partial collection practices of restoration practitioners and botanic gardens. According to Havens, Vitt and several other conservationists working at the Chicago Botanic Garden, "the lines between restoration seed sourcing and assisted migration have already begun to blur," given that restoration ecologists are already forced to extend their seed sourcing ranges and expand their practices from strict to relaxed, composite and even predictive provenancing.[48] In parallel, the evaluation of existing germplasm collections kept ex situ in view of utilising them for potential assisted migration projects reveals profound insufficiencies in sample size and diversity. The robustness of ark-paradigm collecting is undergoing a sober re-evaluation by scientists asking whether these collections could be useful for transformative projects. Havens and Vitt, in another article co-authored with their colleagues, state that:

> while capturing taxonomic breadth, banking a single representative sample does not provide a reasonable conservation collection. [...] One of the chief obstacles of the strategy outlined here is the optimal use of seed-banked resources, as banked germplasm does not generally exist in the quantities necessary for either restoration or assisted migration. Research into optimal germplasm multiplication methods, to retain the genetic diversity of the source population, disallow artificial selection and limit the potential of genetic drift, is necessary to fully implement assisted migration in the most rigorous manner possible.[49]

In analysing the effect of assisted migration on the structure of the institutions in which it is being experimentally produced and tested, I follow Joanna Radin's analysis of frozen tissue collections in zoos and natural history museums. As she reminds us, this material is not simply passive or constricted by a stable ontological status: "each new use [of cryopreservation] as well as each new fantasy mutates a horizon of expectation in which frozen materials will reveal new and previously concealed forms of value."[50] Similarly, every new transformative proposal torques the entire field of conservation biology, as well as the internal structure of ex situ institutions, through a process that has as much to do with a shift in regimes of truth (as sketched out in Foucault's genealogical writing) as with the reorganisations of chains of references and laboratory assemblages by nonhuman entities studied by Latour. The conservationists invested in assisted migration projects are now in the position of having to ask new questions of their seed

[48] Havens et al., "Seed Sourcing for Restoration," 126.
[49] Vitt et al., "Assisted Migration of Plants," 25.
[50] Joanna Radin, "Planned Hindsight," *Journal of Cultural Economy* 8, no. 3 (4 May 2015): 361–78, 372.

collections: are they diverse enough in genetic variability and origin? What is their provenance? Is it important that they be sourced locally, or do severe ecosystemic disturbances render that question irrelevant? What is their adaptive potential? What are the risks of genetic drift or maladaptation according to the amount of range mixing in the sample? How will they propagate once banked?

Whether assisted migration projects will be effectively implemented on a larger scale in the coming decades or not, they are already changing scientists' perceptions of their currently available collections. Shifts in world-making practices can be read in and through the problems encountered by various conservation projects, and in the material practices undertaken in response. What we see sketched out here are the materially significant differences between stockpiling and world-making projects: a seed does not have the same agency and potentiality when it is banked as a relatively static sample to be replanted when the ark lands as when it is meant to become an agent for landscape engineering, or at least destined to recolonise disrupted ecosystems and form entirely new communities in blasted landscapes. The question that restoration practitioners and conservation biologists are asking here is: how does one collect for something that is to become a world, and will enable the continuation of worlds?

3. Stockpiling and Governance

This re-evaluation of the criteria by which seeds and plants should be collected is symptomatic of current changes in how conservation institutions understand and govern endangered species. The question of changing modes of governance in ex situ conservation institutions has most recently been explored by Katja Grözner Neves: she resituates botanic gardens within the wider history of modern governance techniques, arguing that they have often acted as catalysts for the developments leading to the formation of modern nation-states, and analysing contemporary transformations integrating Anthropocene discourse, computational analytics, and "posthuman" concepts of multispecies entanglements into conservation practices and policies.[51]

While Neves' exploration of emerging forms of governance in botanic gardens is a timely and rich addition to studies of the material and ontological politics of ex situ

[51] Neves, *Postnormal Conservation*, 3.

conservation, her use of the modifier "postnormal" (a term she borrows from Mike Hulme) to describe the emerging type of science being conducted is questionable.[52] Neves conflates the Foucauldian analysis of governmentality with the issue of the politico-administrative reach of the modern nation-state, her definition of neoliberal conservation only extends to market-based approaches to revaluing nature through economic policies, and she discusses the neoliberalisation of botanic gardens mainly through the lens of the "rentability pressures" and increased competition for funding.[53] Neves cites Timothy Luke's definition of a new "florapower" exercised by botanic gardens, which "adjusts the accumulation of valuable plants [...] to suit market exchange, while at the same time, checking any unsustainable growth that could threaten these assets," and follows his identification of neoliberal rationality with market policies.[54] This leads her to establish three different tendencies emerging in conservation governance – the "neoliberal environmentalities of 'nature' preservation, the emergence of computational analytics as a type of environmental governance (i.e., as computational governmentality), and [the] posthuman opportunities for the kinds of multispecies conviviality that supposedly overcome the objectification and exploitation of nonhuman plant natures". She also argues that environmental governance in the Anthropocene cannot be adequately theorised within the parameters of theories of governmentality developed to study the modern nation-state, such as Foucault's analysis of governmental rationality.[55] This is why Neves can speak of a "posthuman governance of human-plant assemblages" as distinct from "the governance of plants as objects of scientific inquiry and/or economic interest."[56]

This argument, while important for theorising the involvement of botanic gardens and their kin institutions in environmental governance, does not open up the conceptual space necessary for thinking about the emergence and harnessing of relational ontologies and multispecies assemblages in what could be called neoliberal conservation. Taking a strictly financial view of neoliberal conservation obscures the way in which integrating these new ontological politics, notwithstanding its liberatory cast, often still serves hegemonic neoliberal aims, especially when analysed through the lens of security and

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[52] Neves, *Postnormal Conservation*, 19.
[53] Neves, *Postnormal Conservation*, 63.
[54] Luke, "The Missouri Botanical Garden," cited in Neves, *Postnormal Conservation*, 64.
[55] Neves, *Postnormal Conservation* 179.
[56] Neves, *Postnormal Conservation*, 180.

circulation. In this respect, Luigi Pellizzoni's analysis of the imbrications between neoliberalism and emerging matters of interest in anti-essentialist scholarship, to which I will turn in the following section, is significantly more useful for understanding what is at stake in assisted migration and in transformative conservation more generally.

The pressure exerted on collection practices by assisted migration projects – which problematises whether ex situ collections are of any use *at all* for future restoration – is part of the changing infrastructural relations and assumptions of environmental governance. What is inscribed into the changes in significance and composition of seed collections for transformative restoration projects is the increasingly prominent urgency of circulatory security, which Foucault emphasised as the most important element in the neoliberal formation of power relations. It represents the culmination of earlier efforts at intervening in the milieu in which endangered animals circulate, as we have seen with attempts at reviving and creating migration corridors. These efforts are faced with the added difficulty that the very milieu in which security "tries to work within reality, by getting the components of reality to work in relation to each other, thanks to and through a series of analyses and specific arrangements" is now mutating beyond any capacity to commodify environmental contingency as calculated risk.[57] Ex situ collections are increasingly evaluated for their ability to ensure the continued circulation of endangered populations, by providing them with sufficient genetic variety and robustness to allow them to effectively take and thrive in the ranges they might be transplanted to. A good seed accession is now increasingly one which allows environmental uncertainty to be integrated into its geographic and genetic composition.

I have not laid out the changes in collection practices merely to point out that botanists are becoming more aware of and invested in multispecies assemblages and their plasticity. The goal is also to show that this increased awareness, and the technological and epistemological innovations – the genetic analysis of collected samples and the modelling of provenance and destination ranges, for instance – that have driven this awareness are precisely what is being harnessed in the service of increased environmental securitisation. As Michael Dillon and Luis Lobo-Guerrero argue, "[b]iopolitical security discourses and techniques deal with an object that is continuously undergoing transformation and change through the manifold circuits of production and

[57] Michel Foucault, *Security, Territory, Population. Lectures at the Collège De France, 1977-78*, ed. Michel Senellart, trans. Graham Burchell (Basingstoke: Palgrave Macmillan UK, 2009), 47.

reproduction which comprise the very eventalness of its biological existence."[58] For ex situ collections to be brought into use and circulation, and for the assumption that a stable stockpile might be enough to regenerate engendered populations to be questioned, represents an intensification rather than an emancipatory destabilisation of biopolitical security techniques.

Nélia Dias and Fernando Vidal have described a historical trend toward an "endangerment sensibility," a term taken up by Frédéric Keck in his study of avian flu preparedness.[59] This recognition of a growing endangerment sensibility provides a complementary analysis of the transformations undergone by animals and plants when they are collected in view of responding to projected but uncertain scenarios of future risks:

> In this new vision of the world, the value of living beings doesn't come from their accumulation for profit, which transforms them into standardized commodities, but from the imagination of future threats, which instantiates a list of priorities and scenarios for interaction. If the environmental value is not intrinsic but depends upon practices of collecting, storing, and classifying, as Dias and Vidal argue, then avian reservoirs create values through the perception of birds and the pathogens they carry.[60]

It is to this sense of intertwined endangerment and potential that I will now turn. While the ark-paradigmatic form of sourcing and collecting is being questioned by assisted migration, ex situ heterotopias also provide the space in which horticultural practices can come to bear on newly emerging vegetal capabilities.

[58] Michael Dillon and Luis Lobo-Guerrero, "Biopolitics of Security in the 21st Century: An Introduction", *Review of International Studies* 34, no. 2 (2008): 265–92, 283.

[59] See Fernando Vidal and Nélia Dias, "The Endangerment Sensibility," in *Endangerment, Biodiversity and Culture*, ed. Fernando Vidal and Nélia Dias (London, New York: Routledge, 2016). On risk as a defining characteristic of late modernity, see Ulrich Beck, *Risk Society: Towards a New Modernity*, trans. Mark Ritter (London: SAGE, 1992).

[60] Keck, *Avian Reservoirs*, 58.

III. Migrants on Unstable Ground

Assisted migration certainly exceeds the scope of ex situ institutions in that it problematises distinctions between in and ex situ solely focused on whether plants and animals are being protected within the boundaries of institutions. This unorthodox restoration practice enables a new form of controlled displacement, which builds on botanic garden cultivation practices and shares certain assumptions with them, while at the same time extending far beyond their remit. It is this tension that I propose to explore now.

We have seen in the preceding section how current transformations of collection practices reveal a growing integration of uncertainty into conservationist modes of governance. This integration goes hand in hand with an ongoing or renewed investment in practices of horticultural cultivation, in a seemingly paradoxical marriage of risk and enforced stability. The unique situation of assisted migration, poised at the confluence of highly regulated cultivation techniques and a form of "governance through disorder," produces endangered species as mobile agents endowed with the capacity to recreate environments in spite of their unique vulnerability to migrational impoverishment. I will turn to this confluence now to analyse how power formations inherited from horticultural genealogies intersect with a growing understanding of Earth, space and ecosystems as mutable and unstable formations, exploring how the management of a fluid wildlife fits into circulatory governance and drives the use of the very technologies that have decimated ecosystems to mitigate that destruction.

In this, assisted migration contains the potential of accelerating the convergence of conservation-biological practices with wide-scale engineering projects. This restoration experiment represents the coming together of a radically new *material* – an ontologically and materially fluid world, species unmoored from their historical ranges – and of a set of pre-existing *methods* – horticulture, silviculture, landscape engineering. While the latter are predicated on what Tsing, Mathews and Bubandt call modular simplifications[61] and work with fungible and predictable biological units, I contend that their potential for designing and managing worlds is multiplied rather than constrained

[61] Tsing, Mathews, and Bubandt, "Patchy Anthropocene," S186.

by the rise of unpredictable and incalculable environmental changes. It is the rational application of horticultural knowledge and power that enables species to move and make their circulation more fluid, and it is through the lens of cultivation that the open, shifting ground crossed by these species takes on the appearance of a space of opportunities. As Pellizzoni notes in his analysis of a neoliberal shift in the technosciences:

> [t]urbulence and contingency, as produced by global trade, innovation-based competition, floating exchange rates, and ecosystems dynamics, do not mean uncontrollability, but lack of limits, room for manoeuvre, opening up of possibilities. Rather than paralyzing, the eventuality of future, or the subjectivity of expectations, enables the construction of purposefully designed task environments where new opportunities take shape.[62]

While Pellizzoni focuses more specifically on carbon markets, GMOs and biological patenting,[63] his analysis can be extended to conservation biology. The contingency produced by changing "ecosystem dynamics" increasingly informs conservation practices, and nowhere more so than in the spaces catalysing emergent, experimental proposals.

1. A Sense of Place

"Even what we call refugia are dynamic," Maurizio Rossetto tells me during the second of two interviews I conducted with him.[64] Rossetto is a senior principal research scientist at the Royal Botanic Garden Sydney, where he helms Restore and Renew, a "replicable framework that interprets uniformly gathered evolutionary, ecological, and genetic data across many species to meet the needs of restoration practitioners."[65] Rossetto is also an outspoken proponent of a wider temporal perspective on species movements, holding both ecosystems and species to be entirely processual, temporal

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[62] Luigi Pellizzoni, "Construction, Co-Production, and Beyond. Academic Disputes and Public Concerns in the Recent Debate on Nature and Society: Construction, Co-Production and Beyond," *Sociology Compass* 8, no. 6 (June 2014): 851–64, 859.

[63] See Luigi Pellizzoni, *Ontological Politics in a Disposable World. The New Mastery of Nature* (London, New York: Routledge, 2016) and Luigi Pellizzoni and Marja Ylönen, eds., *Neoliberalism and Technoscience: Critical Assessments* (London, New York: Routledge, 2016).

[64] Maurizio Rossetto, interview by author, June 4, 2020.

[65] Maurizio Rossetto et al., "Restore and Renew: A Genomics-Era Framework for Species Provenance Delimitation," *Restoration Ecology* 27, no. 3 (1 May 2019): 538–48, 539. The project takes the form of a webtool that combines genetic information and climate modelling in order to suggest ranges from which seeds for restoration projects should be sampled.

constructs, and he is critical of conservation projects working with narrow historical baselines and ignoring the importance of temporal processes. As he sees it, this can lead to absurd decisions, such as Sydney residents opposing the return and expansion of rainforests in the region because this vegetation was not present there during their lifetime. During the two interviews we conducted, he is temporally expansive, to a dizzying degree: according to him, species and communities are much more flexible than we think, undergoing constant and significant range shifts (he cites glacial cycles as an example), and holding on to an essentialist definition of species is irrelevant in deep time. "You will morph into something else," he reminds me near the end of our first conversation.[66]

While Rossetto's perspective on the impermanence of species and ecosystems sits at a processual extreme of conservation biology, it is characteristic of how assisted migration proposals present place and time. As Hällfors and her co-authors point out, the questions of nativeness and locality, categories long mobilised in conservation and restoration efforts, are problematised by climate change – and assisted migration is one possible response to that problem:

> The nature we nowadays consider "native" will eventually change. Therefore, AM [assisted migration] forces us to reevaluate the aim of conserving nativeness through particular legislation against the objective of safeguarding biodiversity in general.[67]

Similarly, legal scholars grappling with the future consequences of assisted migration have noted that conservationists will have to contend with these changing definitions of invasive and native, and one article on the subject points out that the term "neo-native" has already come into use for certain acclimatised species under climate change.[68] And when scientists favourable to assisted migration grapple with the question of invasion risks, they often do so by problematising these definitions. Jillian Mueller and Jessica Hellmann for instance, in an early study of invasion risks, state that:

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[66] Maurizio Rossetto, interview by author, June 20, 2019

[67] Maria H. Hällfors et al., "Assisted Migration as a Conservation Approach Under Climate Change," in *Encyclopedia of the Anthropocene*, ed. Dominick A. DellaSalla and Michael I. Goldstein, vol. 2 (Oxford: Elsevier, 2018), 301–5, 304.

[68] See Julie Joly and Nell Fuller, "Advising Noah: A Legal Analysis of Assisted Migration," *Environmental Law Reporter* 39 (1 January 2009): 10413–25.

> Our study also raises several points regarding the future identification of invasive species under climate change. AM itself confounds the definition of an invasive species because dispersal would be human-mediated and established populations would be outside of the species' native range. If AM projects are successful, however, the introduced population will not be excessively damaging. Moreover, climate change will undoubtedly lead to the creation of new invasive species, without AM, because changing environmental conditions favor some taxa, hinder others, and disrupt ecosystems […].[69]

This new ethos of fluid natures, which inflects established conservationist doxa concerning the respect of historical ranges, seems to converge with current postmodern and poststructuralist investigations into the ungroundedness of material and metaphysical existence. As the term Anthropocene is gaining increasing purchase, environmentalism is shifting toward practices which Jamie Lorimer sees as potentially "valu[ing] and catalys[ing] modes of 'stewardship' based on diverse, reflexive awareness of the [...] indeterminacy of ecology."[70] This indeterminacy also informs Stengers' and Latour's analyses of the ecological, economic and political implications of what the former calls catastrophic times and the latter the Anthropocene. Stengers has emphasised Gaia as a concept useful for speaking about "*intrusion, not belonging*" – the consequence of having provoked a ticklish planet, who might well shrug us off in a gesture incommensurable with the provocation offered by capitalism.[71] By contrast, Latour (writing with Timothy Lenton) argues that the emergence of that figure represents a new reconfiguration of the "dichotomy between necessity and freedom":

> That is the novelty to be addressed and the chance to be seized. When humans look at Gaia, they do not encounter the inflexible domain of necessity but, strangely enough, what is largely a domain of freedom, where life forms have, in some extraordinary ways, made their own laws, to the point of generating over eons multiple, heterogeneous, intricate and fragile ways of lasting longer in time and extending further in space [...].[72]

Latour and Lenton go on to argue that the discovery and visualisation of Gaia extends freedom into the domain of necessity and vice-versa, reminding us of our dependence on intertwined mechanisms of self-regulation. But this conclusion seems weakened by the

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[69] Jillian M. Mueller and Jessica J. Hellmann, "An Assessment of Invasion Risk from Assisted Migration," *Conservation Biology* 22, no. 3 (June 2008): 562–67, 565.

[70] Lorimer, *Wildlife in the Anthropocene*, 4.

[71] Stengers, *In Catastrophic Times*, 44

[72] Bruno Latour and Timothy M. Lenton, "Extending the Domain of Freedom, or Why Gaia Is So Hard to Understand," *Critical Inquiry* 45, no. 3 (March 2019): 659–80, 676.

absence of any critical analysis of how neoliberal governance produces freedom as a necessary element of circulation, and by the assumption that casting Gaia "as a thin biofilm" rather than a sphere gazed at from a disembodied vantage point is enough to undo the possibility of dominion. This assumption neatly elides the question of the horizontal, de-statified ability of neoliberal governance to harness transactions and mobilise resilient agents within that "critical zone."[73]

The rhetorical move enacted by this dismissal of nativeness, its investment in fluid assemblages and its tendency to empty out landscapes and ecosystems, also echoes another, perhaps less nuanced contemporary school of thought. A more extreme response to a newly discovered planetary instability has been explored, for instance, in Emily Apter's review of what she calls "planetary dysphoria": she investigates the emergence of a new "planetary aesthetics" situated at

> the convergence of Naturphilosophie, nihilism, the psychoanalytic soma, speculative materialism and recent ecological science that claims that we are living in the midst of a mass extinction event during catastrophic climate change. […] [T]he planet is conceived of as an environmental death-trap afflicted by radiation, pandemics, dust and stellar burnout.[74]

The geophilosophy Apter traces through the writings of Eugene Thacker, Robin Mackay, Nick Land, Timothy Morton, Félix Guattari and others is cast as a response to "geotrauma." According to Apter, this is thought wounded by and simultaneously embracing radical deterritorialisations caused by a sense of absolute perishability and mutability, and it captures "the geopsychoanalytic state of the world at its most depressed and *unruhig*, awaiting the triumphant revenge of acid, oil and dust."[75] While her diagnosis concerns a set of philosophical, literary and aesthetics extremes, it also characterises the conjuncture in which transformative conservation is emerging as a palatable option; assisted migration, in particular, is bolstered by a *longue durée* perspective on climatic and evolutionary history in which attachment to so-called historic ranges becomes almost risible. In this perspective, it would seem that the task of conservation is now to ensure

[73] See Michel Foucault, *The Birth of Biopolitics: Lectures at the Collège de France 1978–1979*, ed. Michel Senellart, trans. Graham Burchell (Basingstoke: Palgrave Macmillan UK, 2009), 191. For an example of the unacknowledged overlap between Gaia theory, horizontal and resilient network, and neoliberal co-optation, see Alfonso Fernández-Herrería and Francisco Miguel Martínez-Rodríguez, "Deconstructing the Neoliberal 'Entrepreneurial Self': A Critical Perspective Derived from a Global 'Biophilic Consciousness'," *Policy Futures in Education* 14, no. 3 (April 2016): 314–26.
[74] Emily Apter, "Planetary Dysphoria," *Third Text* 27, no. 1 (1 January 2013): 131–40, 134.
[75] Apter, "Planetary Dysphoria," 140.

the smooth transition from one assemblage to the other for all species involved, rather than attempting to keep them where they supposedly no longer belong.

2. Horticultural Expertise

This discursive investment in the inevitability of change does not mean that the proponents of assisted migration eschew an institutional infrastructure allowing for the management of nonhuman life. This point has been emphasised by Mick Smith in his critique of the ecomodernist discourse underpinning support for novel ecosystems. I mention Smith because novel ecosystems have emerged as a conservationist object of concern that shares many characteristics with the assemblages formed through assisted migration. A group of ecologists and biologists – among them the "new ecologists" mentioned in chapter 1 – has recently cast doubt on the usefulness of restoring ecosystems transformed by invasive non-native species. According to them, restoration ecology tends to cling to outdated and unattainable historical baselines, and operate on the basis of an idealised, pre-human nature. Novel ecosystems, defined as "systems that differ in composition and/or function from present and past systems as a consequence of changing species distributions, environmental alteration through climate and land use change and shifting values about nature and ecosystems,"[76] have been altered so radically that they cannot revert back to their pre-invasion state, and it has been suggested that they must now be embraced, studied, and managed as such.[77] Smith's argument is parallel to the one I make in this chapter, and his emphasis on the ties between new conservationists and global corporations. As he points out, the rhetoric of fluid natures and Anthropocene inevitability never comes without an injunction to seek "development by design" and to "partner with corporations in a science-based effort to integrate the value of nature's benefits into their operations and cultures."[78] Here the implicit

[76] Hobbs, Higgs, and Hall, *Novel Ecosystems,* 4.

[77] In addition to Hobbs, Higgs, and Hall, *Novel Ecosystems*, see for instance Nathaniel B. Morse et al., "Novel Ecosystems in the Anthropocene: A Revision of the Novel Ecosystem Concept for Pragmatic Applications," *Ecology and Society* 19, no. 2 (2014): art12, and Michael P. Perring, Rachel J. Standish, and Richard J. Hobbs, "Incorporating Novelty and Novel Ecosystems into Restoration Planning and Practice in the 21st Century," *Ecological Processes* 2, no. 1 (December 2013): 18. For an ecological critique of novel ecosystem discourse, see Daniel Simberloff, "Non-Native Invasive Species and Novel Ecosystems," *F1000Prime Reports* 7, no. 47 (2015).

[78] Kareiva, "Conservation in the Anthropocene," quoted in Michael Smith, "(A)Wake for 'the Passions of This Earth': Extinction and the Absurd 'Ethics' of Novel Ecosystems," *Cultural Studies Review* 25, no. 1 (25 September 2019): 119–34, 126.

ontological politics of novel ecosystems discourse (in which relations, not essences, are foregrounded) and explicit management methods (whose structures of control belie the supposed fluidity of these new assemblages) come into seeming tension, one that resolves into a potential blueprint for the interplay of mastery and freedom also at play in assisted migration.

But before returning to the entanglement of conservationist and capitalist interests, we must examine how this tension between management and fluidity plays out in the institutions where assisted migration is tested. It is important to emphasise that the perspective on landscape, climate, species and assemblage (im)permanence afforded by the literature on the topic comes at no cost to its investment in the specific expertise cultivated in botanic gardens. These institutions often provide the material and testing grounds for the handful of experimental projects that have been conducted so far. Some proponents of assisted migration cast this practice as historically reliant on the specific modes of knowledge-making and surveillance that characterise botanic gardens. And they go even further when anchoring the very justification for plant translocation the history of previous cultivation in botanic gardens. Plants, it is argued, have already been moved in (supposedly) controlled settings, and extending the practice to restoration ecology is not so much a break with as an extension of horticultural practices:

> Translocating plants is nothing new. Humans have been moving plants, particularly edible, medicinal, and more recently ornamental, species throughout our history [...]. Modern horticultural and agricultural industries are responsible for wide scale translocations. […] In addition, there is a tremendous wealth of knowledge resident in the restoration and horticultural communities in this regard, which needs to be formally documented so that it can inform decisions about assisted migration.[79]

Similarly, Schwarzt, McLaughlan and Hellmann argue for integrating horticultural planting into the distributional history of species, naturalising it as a practice which "contributes to passive range expansions." Given this pre-existing entanglement with vegetal histories, the "capacity [of botanic gardens] to actively foster range expansions under climate change" is a new domain to be explored rather than reduced to a pathway for destructive invasions.[80] And this pragmatism extends far enough to encompass the

[79] Vitt et al., "Assisted Migration of Plants," 25.
[80] Schwartz et al., "Managed Relocation," 734.

cultivation of nursery plants, which, it has been suggested, have a head start on climate change thanks to the extension of their natural range through commercial distribution.[81]

The nursery and the garden emerge not only as the ideal space for expanding the ranges of individual species, but also as one of the potential models for future natures in general. This idea that conservation biology is uniquely situated to contribute to a horticultural management of a changing Earth can be found in texts that go beyond the assisted migration debate, but nevertheless participate in a similar discourse. To wit, the recommendations of an article tellingly titled "Botanic Gardens Should Lead the Way to Create a 'Garden Earth' in the Anthropocene":

> Because of this long-term commitment to growing, preserving, and improving plant diversity and their benefits, botanic gardens will be some of the best prepared and equipped to create a "Garden Earth" as we enter the Anthropocene. As humans have come to dominate the planet and the basic dynamics of its water, energy, and nutrient cycles, humanity will necessarily have to become more and more committed to sustaining its natural resources. Our valuable plant resources will need to be actively managed, from the intense production environment of monoculture agriculture to the occasional milder interventions necessary to maintain "natural" areas. [...] The horticultural staff of botanic gardens often already manage plant and trees across this spectrum of form and function, from manicured ornamental gardens, with carefully bred and esoteric plant varieties, to regenerating natural areas containing wild native species. These skills should be employed to make the global transition to a robust green infrastructure with a healthy and diverse population of trees and plants living in the many environments that humans now inhabit.[82]

While not every botanist, conservationist or horticulturalist who I have cited in this section would subscribe to this extreme of management, captivity largely seems to become a testing ground for future managed landscapes, and what is learned from supervision might pave the way for a remaking of nature as a mobile arrangement that can be stitched back together by exerting a finely calibrated control. Vitt et al., for instance, "envision a future where well-conceived translocations of species may reduce the risk of extinction, as well as increase the number of potential taxa creating new assemblages in a fluid landscape responding to broad scale changes."[83]. Seen through the lens of this

[81] See Sebastiaan Van der Veken et al., "Garden Plants Get a Head Start on Climate Change," *Frontiers in Ecology and the Environment* 6, no. 4 (2008): 212–16.
[82] Charles H. Cannon and Chai-Shian Kua, "Botanic Gardens Should Lead the Way to Create a 'Garden Earth' in the Anthropocene," *Plant Diversity* 39, no. 6 (December 2017): 331–37, 333.
[83] Vitt et al., "Assisted Migration of Plants," 19.

particular conservation proposal, nature, recombinant, can be had for movable parts of a moving landscape, and assemblages can be rebuilt starting with a reduced number of "bread-and-butter species" to stabilise communities.[84]

3. Producing Engineers

What to make, then, of the claim of mastery that underpins the very possibility of conducting assisted migration projects, and of its apparent contradiction with the intensely processual character conservation seems to adopt in these projects? The apparent contradiction between mobilising the rhetoric of a fluid nature and applying an expertise accumulated in projects of control is lessened when one considers the consequences of making ungroundedness the basis for ecological thought. While Apter's analysis remains at the level of a diagnosis of geotrauma and its repercussions in art, literature and philosophy, Nigel Clark goes further in unfolding the political consequences of insufficiently critical calls to extend agency beyond the human and to explore the enmeshment of human life with nonhuman nature, most notably in actor-network theory and relational ontologies. Flattening material existence into a set of commensurable or at least symmetrical networks does away with necessity and with resistance, suggesting the always available possibility of assembling things differently than they are and of negotiating reality entirely, without remainder. Clark concludes that "a cosmos which is assembled step by step is a cosmos that can be re-assembled step by step."[85] This agency without any opacity or remnant of inaccessibility is precisely what is suggested when biologists consider the possibility of intervening in disturbed and mutable ecosystems by implementing predictable techniques for rearing, growing and tending to plants. If taken up uncritically, or with the enthusiasm of ecological modernism which Smith characterises as a naturalisation of capitalist depredations, it seeds one possible tendency toward "a massive expansion of the dominions of being upon which collective human agency imagines it has purchase."[86] Thus the question posed by the interplay between radical openness and horticultural management touches on what is potentially being assembled, or reassembled, in assisted migration: besides the possibility of remaking

[84] Havens quoted in Anne Raver, "A Hunt for Seeds to Save Species, Perhaps by Helping Them Move," *The New York Times*, 9 November 2009, sec. Science.
[85] Nigel Clark, *Inhuman Nature: Sociable Life on a Dynamic Planet* (London: SAGE, 2011), 51.
[86] Clark, *Inhuman Nature*, 51.

ecosystems, scientists make novel assumptions about the kind of subject these movable plants are, and to what extent they can be made to act.

One crucial aspect of the horticultural context in which assisted migration candidates are thought, managed and reproduced is that it is not only a *disciplinary* practice. Controlled seedling transplants can be framed as nursery practices, and the expertise needed to manage plants outside of their original ecosystem certainly ties into a longer genealogy of acclimatisation processes and the enrolment of exotic plants into the aims of "nature's government."[87] But assisted migration differs markedly from these practices in that it does not aim to reproduce compliant and standardised subjects. Its projects and plots are experimental, and they are so open-endedly; while projections, simulations and models are commonly used by scientists to determine which species might be suited to which future range, performing predictably is neither expected nor fully sought.

Thus, the botanical (and zoological) garden practices that enable assisted migration test-studies do not tend to a reproduction of captivity. This observation is based on the question asked by Friese in her study of cloning practices at the zoo: rather than focusing either on the controversy surrounding cloning, or on the effective applicability of these proposals, she asks first how these practices stitch nature and culture together in different ways, and later what these projects reproduce – which species, but also which practices.[88] Her attention to the "cultures of nature [that] are produced and contested as people create the next generation of endangered animals" is useful for puncturing the assumption that captive breeding and ex situ conservation enact a homogeneous form of captivity, and *only* this captivity.[89] Assisted migration, like cloning projects, carries a variety of biological and social processes of reproduction into the future, even as it makes use of pre-existing structures of captivity. While it is built on techniques that force and select for compliance, it subjectifies endangered plants by utilising the model of the entrepreneurial self, flexible, adaptive, and ultimately an active participant in shaping the future of its new environment.

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[87] As Richard Drayton calls it in his eponymous study of botany and imperialism. See Richard Drayton, *Nature's Government. Science, Imperial Britain and the 'Improvement' of the World* (New Haven: Yale University Press, 2000).

[88] See Friese, *Cloning Wild Life* for the first phase of this research, and Friese, "Cloning in the Zoo: When Zoos Become Parents," in *The Ark and Beyond: The Evolution of Zoo and Aquarium Conservation*, ed. Ben A. Minteer, Jane Maienschein, and James P. Collins (Chicago: University of Chicago Press, 2018), for her later reconceptualisation of her research terms.

[89] Friese, "Cloning in the Zoo," 273.

Nowhere is this clearer than in the discussions around community, invasiveness and hybridisation that are being conducted in the literature on assisted migration. Assisted migration has been discussed as an example of possibly outdated single-species approaches, notably by Sandler, Ricciardi and Simberloff, and Soulé.[90] Their position, to summarise it briefly, is to contend that the "[p]reservation of species habitats […] and interconnections among species […] are of higher importance than single species survival per se, which makes assisted migration an unacceptable option, or at least one to be approached with extreme caution."[91] But other publications belie this characterisation by stating the expectation that the translocated species will involve themselves in the crafting of new relations and assemblages.

One pathway to this involvement is a particular form of semiotics via hybridisation, as a form of adaptation and integration into new ecosystems. Ricciardi and Simberloff have pointed out, albeit in an admonitory mode, that "the biological traits that promote endangerment are not simply the opposite of those that favor invasiveness"; the potential for species to become invasive is almost unpredictable, and in particular when the calculation includes the possibility that a migrating species will facilitate the expansion of others by dispersing, pollinating, or otherwise interacting with them.[92] It is precisely this entrepreneurial plasticity that proponents of assisted migration see as an opportunity. While Stanturf et al.'s assertion that "transformational restoration will create novel ecosystems by moving species far beyond their historical ranges" might sound problematic to scientists not working, as the authors do, in commercial forestry, their suggestion that "a certain amount of invasiveness and hybridization may be desirable in assisted migration to facilitate establishment of new species or transfer of adaptive traits into native populations" echoes the pragmatic view of species as processes adopted by biologists working on transformative conservation projects.[93] When I met him

[90] See Ronald Sandler, "The Value of Species and the Ethical Foundations of Assisted Colonization," *Conservation Biology: The Journal of the Society for Conservation Biology* 24, no. 2 (April 2010): 424–31; Ricciardi and Simberloff, "Assisted Colonization"; and Michael E. Soulé et al., "Strongly Interacting Species: Conservation Policy, Management, and Ethics," *BioScience* 55, no. 2 (1 February 2005): 168–76.

[91] As summarised in Isabelle Aubin et al., "Why We Disagree about Assisted Migration: Ethical Implications of a Key Debate Regarding the Future of Canada's Forests," *The Forestry Chronicle* 87, no. 06 (December 2011): 755–65, 763

[92] Ricciardi and Simberloff, "Assisted Colonization," 251.

[93] John A. Stanturf et al., "Transformational Restoration: Novel Ecosystems in Denmark," *Plant Biosystems - An International Journal Dealing with All Aspects of Plant Biology* 152, no. 3 (4 May 2018): 536–46, 537 and 539; see also R. Kasten Dumroese et al., "Considerations for Restoring Temperate Forests of

for the first time in his office at the Royal Botanic Garden Sydney, Rossetto expanded on how hybridisation and climatic niches interact: two species that hybridise in a specific climate can undergo a reverse process of speciation once the niches differentiate enough again to bring forth the specifically adapted traits they both possess.[94] Species as reservoirs for one another, a healthy dose of invasiveness as a necessity for survival, and hybridisation as the metamorphic borrowing of traits that facilitates communication and integration: all these elements combine to make assisted migration candidates into mediators, diplomats, and cosmopolitan entrepreneurs.[95]

This shift in capabilities can also be read as a taxonomic migration. While assisted migration was originally proposed for both plants and animals, it has predominantly been taken up in botany, a shift that can be read as inverse to the one Timothy Nealon describes in his "archaeology of biopower" in Foucault's work.[96] Nealon notes that, contrary to what critical readings of Foucault's animal blind spot would suggest, it is not animal life that was excluded in the advent of biopolitics, but plant life. In *The Order of Things*, Foucault distinguishes the "grid of knowledge constituted by natural history" from its successor, biology, by its insistence on structure.[97] "Hence," according to Foucault, "the epistemological precedence enjoyed by botany" during the Classical age: the greater availability of plants to the scientific regime of visibility and description of forms made them the perfect taxonomic subjects, which could be represented from root to tip and known completely.[98] Only with the end of natural history came the advent of the animal as the privileged template of what life is and does.[99] In Nealon's words, "the living is no longer primarily vegetable (sessile and awaiting mere categorization) but understood as evolving, appetite-driven, secret, discontinuous, mendacious, inscrutable, always on the prowl, looking for an opening to break free."[100] Which begs the question: does this

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Tomorrow: Forest Restoration, Assisted Migration, and Bioengineering," *New Forests* 46, no. 5 (1 November 2015): 947–64.

[94] Maurizio Rossetto, interview by author, June 20, 2019.

[95] See Vinciane Despret, "Traits," trans. Matthew Chrulew, *Environmental Humanities* 12, no. 1 (1 May 2020): 186–89.

[96] Nealon, *Plant Theory*, 7.

[97] Foucault, *The Order of Things*, 139. He characterises natural history as "a science, that is, a language, but a securely based and well-constructed one: its propositional unfolding is indisputably an articulation; the arrangement of its elements into a linear series patterns representation according to an evident and universal mode." (Foucault, *The Order of Things*, 148)

[98] Foucault, *The Order of Things*, 137.

[99] "The plant held sway on the frontiers of movement and immobility, of the sentient and the non-sentient; whereas the animal maintains its existence on the frontiers of life and death." (Foucault, *The Order of Things*, 303)

[100] Nealon, *Plant Theory*, 8

discourse about inhuman dynamism and plants as adaptive ecosystem engineers reactivate this shift in templates? Is treating plants as assisted migration candidates a form of animalisation of vegetal life? And what epistemological and ecopolitical shifts does this augur? Animalised, migrating vegetal life leaves the realm of the disciplinary plantation and the scientific garden, and fully enters that of biopolitics – newly capable, but also newly governable and exploitable.

4. Plantations and Alien Planets

The current conjunction of increased geographic fluidity with the technologies of horticultural care thus results in this transformation of plants into active, entrepreneurial participants in the design of their new environments – even if it is merely a projection and not yet a fully realised reality. These two elements are not so much contradictory as they are complementary, at least when they are connected strategically by a specific form of governmental rationality. As Clark reminds us, construing material existence as entirely negotiable may, without proper attention to remaining asymmetries and non-negotiable inheritances, lead to an expanded dominion of human agency rather than to precise and polite attention to nonhuman agents. This tendency has similarly been framed by Pellizzoni as one of the defining characteristics of neoliberal governance applied to a nature dissolving into disorder: he observes that patents, carbon credits and weather derivatives seem to assert ontological indefiniteness rather than attempt to reproduce a distinction between nature and culture, and that they exert power over nonhuman nature by doing so. The hypertrophy of human agency, he concludes, goes hand in hand with the dissolution of ontological borders and essences:

> Neoliberal governance, thus, seems to entail a subtle and novel conceptual move. One pillar of modernity is abandoned: the core distinction between inner and outer worlds disappears in favour of what, to all intents and purposes, is an anti-essentialist ontology. At the same time, another pillar of modernity, traditionally linked to the idea of objective knowledge, is reaffirmed and expanded in scope: human agency as having capacity of control.[101]

[101] Luigi Pellizzoni, "Governing through Disorder", 799.

It seems, then, almost inevitable that a conservation proposal predicated on the acknowledgement of nature as fluid rather than fixed, ephemeral when surveyed from the correct temporal perspective, and meant for constant recombination, would serve engineering ambitions well. As I have shown in the previous section, the translocation of plants in highly regulated experimental plots, botanic gardens and in-situ plantations can be analysed as the making of adaptive and entrepreneurial subjects; Jeffrey Crooks, for instance, characterises invasive plants as ecosystem engineers and points out that "only recently has the concept of ecosystem engineering been developed to account for the role of species that shape habitats."[102] Assisted migration itself has been called an "ecosystem engineering technology" by some of its detractors. Maier and Simberloff contend that while assisted migration started out as a proposal for conserving biodiversity, "ecosystem engineers already focused on rather different goals quickly saw AM as a means to serve these, too. AM is now also proposed as means to preserve, establish, or enhance 'ecosystem services.'"[103] For them, this recuperation is an opportunity to dismiss the entire enterprise on the grounds of danger and hubris, but the indictment merits further attention.

The possibility of harnessing assisted migration for ecosystem engineering proposals has been taken up in a study by researchers in biogeography at the University of Bayreuth. They suggest using plants as sentries for establishing climate refugia, which they would do by creating stable ecosystems outside of their current climatic ranges for other species to move to when the need arises. The species used as the vanguard of such movement "could be called core species, keystone species, structural species, ecosystem engineers or, as further used here, foundation species."[104] Moving foundation species first, according to the authors, would resolve the issues plaguing the translocation of rare

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[102] See Jeffrey A. Crooks, "Characterizing Ecosystem-Level Consequences of Biological Invasions: The Role of Ecosystem Engineers," *Oikos* 97, no. 2 (2002): 153–166.

[103] Donald S. Maier and Daniel S. Simberloff, "Assisted Migration in Normative and Scientific Context," *Journal of Agricultural and Environmental Ethics* 29, no. 5 (1 October 2016): 857–82, 858. While this might be anecdotal, it is worth pointing out here that at least one of the main scientists involved in the assisted migration debate, Jessica Hellmann, is now an investigator in a research group on the "*Ecological* Impacts of Solar Radiation Management Geoengineering" (see "NSF Award Search: Award#1937619," National Science Foundation, 2 July 2019) and has founded the private venture Geofinancial Analysis, which monitors the methane emissions for stakeholders and "uses financial tools and scientific knowledge to leverage the capital markets to change human impact on the physical world and improve the odds of averting catastrophic climate change." ("About Us," Geofinancial Analytics, accessed 17 November 2020, https://geofinancial.com/community.)

[104] Juergen Kreyling et al., "Assisted Colonization: A Question of Focal Units and Recipient Localities," *Restoration Ecology* 19, no. 4 (July 2011): 433–40, 436.

endangered species – the absence of an adequate recipient range, the impossibility to source a robust enough population without depleting the original range, and the genetic impoverishment of the remaining pool of individuals. This article makes an explicit link to translocation practices in forestry, a significant element given that it is the one area outside of conservation biology in which assisted migration has been taken up most enthusiastically and practised most extensively.

While it is slightly removed from the case studies which interest me here – involving species which, for all their manageability, are still classified by those who would move them as wild – this article does provide an illustration of what assisted migration would become in a context focusing on managing a specific landscape as a resource. Forestry is a land-use science, and while it has converged increasingly with conservation biology in the past few decades, it remains closer to agriculture in its structure and objects.[105] This genealogy is particularly obvious when foresters mention or are quoted on assisted migration, and their vocabulary of productivity and management. Juergen Kreyling et al, for instance, state that:

> A different view prevails in forestry, where economic benefits (i.e. a high and stable productivity of ecosystems) are given top priority. This reasoning shifts the focus of attention from taxonomic units to the stability and productivity of a given geographic unit. The discussion about assisted colonization among conservationists might benefit from an acknowledgement of this view, as the creation of habitats adapted to climate change might meet several conservation goals.[106]

In the same vein, Stanturf et al. present a new project to test the suitability of trees from the Caspian forests in Iran for translocation to Danish forests and note that Danish forestry has been relying on the introduction of non-native species for at least 150 years. They go on to state that "extreme events present opportunities to transform ecosystems and incorporate more novelty in the near-term."[107]

Forestry, in fact, is an excellent template for understanding how neoliberal environmentality builds on sovereign state power. As James C. Scott argues, scientific forestry (as it was developed in the late eighteenth century in Saxony and Prussia) is a

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[105] It is often grouped with agriculture under the acronym AFOLU (Agriculture, Forestry and Other Land Use). See for instance Paul A. Wojtkowski, *Undoing the Damage: Silviculture for Ecologists and Environmental Scientists* (Enfield, New Hampshire: Science Publishers, 2006).

[106] Kreyling et al., "Assisted Colonization," 434.

[107] Stanturf et al., "Transformational Restoration," 537.

useful model and metaphor for the mechanisms by which the imperial thinking of European nation-states rendered nature as simplified, legible, calculable, and manipulable.[108] The simplifications that characterise scientific forestry, which views trees through the lens of revenue needs and inventories them as standardised trees in standardised plots, echo the transformations in "urban planning, rural settlement, land administration, and agriculture" undertaken by nascent European nation-states at the time.[109] Not only were forests mapped, plotted and apprehended through a uniform administrative grid; these practices ultimately led to the utopian dream of actively *creating* carefully crafted forests that would be more amenable to being measured and manipulated.

While the land-use science mobilised in the creation of these regimented German forests was dealing with a disorder supposed to be merely local and tameable by management plans and state visions, its legacy is still present in forest management in an age of untameable disorder. The hollowing out of places and ecosystems by the rationality of monoculture, which produces the commensurable and fungible *Normalbaum*, created the homogenised space in which the circulatory abilities of nonhumans can expand. These movements now culminate in an "Anthropocene proliferation" that is but the latest transmutation of an imperial project of planetary disruption.[110] As Foucault has emphasised, apparatuses of power operate by a constant "strategic completion": they are remobilised in order to manage the unintentional effects they have produced.[111] This is how assisted migration is mobilised when scientists propose to reach for agronomic and forestry techniques to undo the violent smoothing out of the world produced by the projects enabled by these very same techniques. In doing so, they repurpose the destabilising effects of sovereign regimentations of the environment into circulatory opportunities for neoliberal environmentality.

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[108] See James C. Scott, "State Simplifications: Nature, Space and People," *Journal of Political Philosophy* 3, no. 3 (1 September 1995): 191–233. See also James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven and London: Yale University Press, 1998).

[109] Scott, "State Simplifications," 42.

[110] Tsing, "A Threat to Holocene Resurgence," 53. Tsing contrasts these proliferations with what she calls Holocene resurgences, which are the slow, collaborative, and sustainable assemblages that form after environmental disturbances. Anthropocene proliferations – the unchecked circulation of deadly pathogens, for instance – are born in simplified and highly vulnerable plantation ecologies, and block the possibility of forming new liveable ecologies through processes of resurgence.

[111] Michel Foucault, *Power/Knowledge: Selected Interviews and Other Writings, 1972-1977*, ed. Colin Gordon, trans. Colin Gordon et al. (New York: Pantheon Books, 1980), 196.

This places assisted migration within one more possible continuity, one more potential future genealogy, with which I will close this section. Smoothed out and empty spaces, the extension of possibilities for escaping degraded conditions, the harnessing of nonhuman agency and activity and the shift of heroic engineering projects from state to private actors coalesce most pointedly in technoscientific fantasies of terraforming other planets. Here too, conditions made unliveable are escaped by the application of the very techniques that have created this uninhabitability – a reverse terraforming, or terrorforming, as Daniel Macfarlane calls it.[112] James Edward Oberg, a former NASA engineer and space journalist and historian, gave his 1981 volume on terraforming – *New Earths* – a telling subtitle: *Restructuring Earth and Other Planets*. In addition to presenting an overview of terraforming possibilities for Mars, Venus and several smaller bodies such as Mercury and the moons orbiting earth and Jupiter, the book contains an entire chapter called "Restructuring Earth." As Oberg makes clear in the introduction, "terraforming has a great deal of promise even if we never consider other planets at all."[113] Terraforming the earth itself, according to him, would provide a safeguard against the impending end of the interglacial period we find ourselves in (anthropogenic climate change does not feature as a factor of disruption here) and a variety of other catastrophes; imagining these technological advancements allows Oberg to reflect back on what he sees as a duty to act as "wardens" to the entire planet by rebuilding it. He does not mention much in the way of remaking ecosystems, but other autors have suggested that plants might be used to transform the Martian atmosphere and gradually return it to its previous – warmer and wetter – climate.[114]

At least one such experiment in climate engineering has been conducted on Earth: Ascension Island, in the middle of the South Atlantic, was "terraformed" between 1860 and 1870 on the insistence of the naturalist Joseph Hooker, and with the Kew's assistance.[115] In more recent times, concepts developed and refined in the context of

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112 Daniel Macfarlane, "Terror-Forming the Earth," *NiCHE* (blog), 9 July 2018, https://niche-canada.org/2018/07/09/terror-forming-the-earth/.

113 James Edward Oberg, *New Earths: Transforming Other Planets for Humanity* (Harrisburg: Stackpole Books, 1981), 36.

114 See for instance James M. Graham, "The Biological Terraforming of Mars: Planetary Ecosynthesis as Ecological Succession on a Global Scale," *Astrobiology* 4, no. 2 (June 2004): 168–95, and James M. Graham, "Stages in the Terraforming of Mars: The Transition to Flowering Plants," *AIP Conference Proceedings* 654, no. 1 (17 January 2003): 1284–91.

115 See David M. Wilkinson, 'The Parable of Green Mountain: Ascension Island, Ecosystem Construction and Ecological Fitting', *Journal of Biogeography* 31, no. 1 (2004): 1–4.

space exploration seem to have seeped back into the conservationist vocabulary; the idea of assisted migration opening the door to thinking about "floraforming" has already been put forward.[116] This is of course not a logic immanent to assisted migration projects, or even explicitly supported by most of their proponents, but it is one element composing the "postnormal" landscape of contemporary conservation biology, which has been shifting towards a greater complicity with neoliberal expansions into imagined off-planet terra nullius. Taking a cue from Scott once more, I wonder whether assisted migration might not be a prosthetic element allowing an institution to "see," to apprehend the world ordered through a specific grid: refracting a view of landscapes as smooth, simplified and in flux onto the earth itself, it could be mobilised to expand the imaginary of outer-space conquest to include the planet as it is now, enabling a gaze from the outside embracing it as an alien world whose components can be rearranged at will.

Space exploration is one element in the topology of practices influencing and transforming conservation biology; one more turning of the screw has been added to conservation biology by the technological-military irruption of the Earth seen from outside and above into the collective consciousness and specific scientific practices.[117] The emergence of the environment as global and planetary was made possible by the rise of distancing and globalising visual, sensing and control technologies. Along with casting Earth as an exceptional and well-regulated vessel as fragile as it is formidable, a "pale blue dot" where life is contained, placed in the universe, and grounded, these technologies might also have enabled the contrary movement of an extraterrestrialisation of the planet now made alien and strange by distance. Only through the distancing already performed by ex situ conservation is it possible to look back at the planet and see it refracted as matter to be intervened in through the judicious application of life and its adaptive powers. If in-situ conservation can be said to aim for a "Holocene museum," in which a good Anthropocene would just be a Holocene saved and suspended,[118] ex situ

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[116] This is from a personal communication by Peter Wharton, curator of the Asian Garden of the University of British Columbia Botanical Garden (cited in Connie Barlow, 'Deep Time Lags: Lessons from Pleistocene Ecology', in *Gaia in Turmoil. Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis*, ed. Eileen Crist and H. Bruce Rinker [Cambridge, Massachusetts: MIT Press, 2009], 169).

[117] See Sebastian Vincent Grevsmühl, *La Terre Vue d'en Haut: L'invention de l'environnement Global* (Paris: Seuil, 2014). The interplay between visualisation techniques, space travel, and ecology has also been examined in Haraway, *Modest Witness.*

[118] "(...) the Isle of Man is, indeed, the Earth in the Anthropocene. It is enclosed, ultra-small (…), an Anthropocene biosphere whose ultimate ambition may be defined as becoming an artificial Holocene – a Holocene sustainable over long periods of time, thereby freezing and eternalizing the evolutionarily produced, hence somewhat arbitrary content of holocenic Earth." (Daniel Falb, "Isle of

conservation, while also operating through miniaturisation and enclosure, might be stockpiling the components for a future alien analogue of what the Earth once was, with a mandate to tinker for maximal inhabitability rather than exact reproduction.

But here, too, some caution and slowness are necessary. Arguing that assisted migration is aligned with terraforming fantasies and that it could be mobilised to serve an engineered overhaul of the planet means accepting the assumptions of the most enthusiastic literature on the subject uncritically. The possibility of scaling such projects – and thus ensuring a continuous trajectory of floraforming expansion – is not conclusively established. As I mentioned at the beginning of this chapter, efforts to test the feasibility of assisted migration projects, not to speak of actually realised translocations, are still few and far between. And while this can be a function of institutional contingencies (the CO-ADAPT project ultimately wound down because it could not secure funding for longer than four years[119]), this dearth of concrete examples is due to other forms of biological and historical resistance which we must now attend to. Migrating species are fluid, but not necessarily quite in the way some wildlife managers want them to be, and they prove to be unexpectedly recalcitrant in ways that shed a very different light on interventionist aspirations. This comes with potential destabilising consequences for this entire enterprise, and for the apparent self-evidence of the cosmoecological order that underpins it.

Man. Poetic Co-Evolution towards the Holocene Museum," *Anthropocene Curriculum* (blog), 23 April 2016, https://www.anthropocene-curriculum.org/contribution/isle-of-man)

[119] Maria Hällfors, interview by author, June 2, 2020.

IV. Speculative Openings

1. Models, Populations, Individuals

In order to widen the scope of this analysis and grasp how assisted migration performs cosmological work, we must approach it from another angle, indebted to anthropological literature. Emphasising only standardised techniques of management and the globalised fantasies of intervention elides the concrete difficulties encountered in the singular, emplaced practices of the conservation biologists I have cited throughout this chapter. This does not diminish the importance of neoliberal governmentality or environmentality in shaping the context in which assisted migration has become a thinkable and palatable option to some scientists; but I argue that assisted migration proponents are engaging in a host of negotiations that puncture governmental rationality, or at least forms its speculative double.

One way of characterising the double nature of assisted migration practices is through a distinction made by the anthropologist Eduardo Viveiros de Castro between model- and example-thinking. Viveiros de Castro proposes this distinction as one element towards answering the question of how to make room for others in the Anthropocene. Model-thinking is one of the ways in which "eco-capitalist thinkers" (a category in which he includes the Breakthrough Institute and accelerationist scholars) try to bring about what they call a "good Anthropocene." Model-thinking, according to him, serves a "political domination over all life," and one of its privileged forms is that of large-scale geo-engineering projects – a term in which Viveiros de Castro also includes, significantly, the violently simplified ecologies of plantations and other capitalist modes of production mentioned by Tsing. [120]

Model-thinking characterises the attitude of the engineer, a definition in which Viveiros de Castro follows Lévi-Strauss's contrasting of mythical imagination and modern scientific practice. As Viveiros de Castro summarises, "the bricoleur is inspired by former examples of the kind of work she or he is engaged in; the engineer follows a model of his/her own design."[121] Geo-engineering works with such normative models –

[120] Eduardo Viveiros de Castro, "On Models and Examples", S299.
[121] Viveiros de Castro, "On Models and Examples," S300.

technocratic, political instruments enforcing a separation between engineers and the humans, nonhumans, landscapes and ecosystems that are to be modelled. But Viveiros de Castro emphasises the coexistence of model-thinking with another mode of thought he terms the *example* – not the moral exemplar used for the governing of conducts, but the characteristic mode of *bricolage* creativity.[122] Instead of using models as norms, this approach uses them heuristically to understand reality, and to "unpredict" it. This example-thinking will be my guide in the final section of this chapter, as I examine possible provocations and disruptions of geo-engineering model-thinking, and instances in which conservationists and restoration practitioners fall back on "extramodern" example rhetoric.

Viveiro de Castro's distinction between model- and example-thinking, while not always neatly applicable to the transactions that characterise conservation biology, is of heuristic usefulness when it comes to following the unexpected effects of transformative or experimental proposals. One of these effects, in the case of assisted migration, is to destabilise a set of assumptions about the possibility of forecasting, modelling, or scaling any project of restoration, transformative or otherwise. I have already touched upon the difficulties encountered by botanists and restoration ecologists when sourcing seeds for projects that have to contend with climate change and its effects; here I will briefly unfold some of the effects these difficulties have on the would-be abstractability and fungibility of the members composing endangered populations.

The problem of seed provenancing is not the only issue conservationists and restoration practitioners are currently grappling with. The question of when seed sourcing and sampling in itself will have reached its limits in terms of usefulness, and whether it is still possible to bank endangered species for restoration at all, is another ripple effect of the displacements caused by climate change. Peggy Olwell, the Plant Conservation Program Lead for the Bureau of Land Management (USA), is quoted in an article of *The New York Times* saying that "frankly, we don't know what it is we're going to need when we're talking restoration in light of climate change. It's going to be one big experiment."[123] Rossetto, however, would go one step further: during our second interview, he made the surprising statement that "what seed banks hold is pretty

[122] Viveiros de Castro, "On Models and Examples," S300.
[123] Quoted in Raver, "A Hunt for Seeds."

irrelevant."[124] By this, he means that ex situ accessions are necessarily unrepresentative of the breadth and distribution of a given species. In fact, according to him, "general rules and guidelines are completely useless" when it comes to restoration. One of the reasons why the Restore and Renew framework developed by Rossetto and his colleagues does not offer recommendations on how to move species (while providing information on how climate change is impacting species distribution and how to adjust seed sourcing) is that the models are "not quite there yet"; they can tell practitioners something about the current distribution envelope of a species, but nothing about its potential. And this potential, he insists, is highly dependent on the individual selected to be planted in a specific place – the accidents of variability, germinative ability, and individual mutations are a crucial component of restoration success. Distribution models are not sufficiently refined to take into account the full breadth of environmental factors such as soil types or potential interspecies competition, and therefore to provide adequate forecasting of where to move threatened plants.

Increased individualisation, and an acknowledgement of the limits of generalisations on the level of the species, is a phenomenon common to conservation projects taking place in disrupted or hybrid environments. Steve Hinchliffe is one of the scholars who pointed out how attention to individuals is enforced in conservation biology, and with what effects. In his study of urban conservation efforts with water voles, he shows that urban conservationists are dealing not with a species but with individuals that are "not simply representative of other water voles"; they perform differently than expected in one particular site in Birmingham, displaying unexpected relationships with brown rats and making straightforward recommendations for how to conserve the riverbanks they inhabit impossible. Hinchliffe shows how conservation strategies are complicated once scientists start viewing "species as processes, as being reconstituted through overlapping though differentiated populations, whose simultaneous differentiation and compatibility are conditions for its success." [125] Assisted migration operates in an analogous space, in which the possibility of treating populations as largely homogeneous groups made up of undifferentiated or fungible individuals becomes increasingly difficult. As Hällfors et al. point out,

[124] Maurizio Rossetto, interview by author, June 4, 2020.
[125] Steve Hinchliffe, "Reconstituting Nature Conservation: Towards a Careful Political Ecology," *Environmental Economic Geography* 39, no. 1 (1 January 2008): 88–97, 94.

> another potential source of model error is the assumption that species are ecologically uniform in their climatic tolerances across their range. Typically, SDMs [species distribution models] treat a species as a single entity, although populations of many species differ due to local adaptation or other genetic differentiation.[126]

Life on the move, it seems, is resistant to being forecast in a way that allows simulation as a pastoral technique of power, which Frédéric Keck understands as "ways to mobilize populations under a common threat in which some are sacrificed for the sake of others."[127]

2. Reordering Relations

My aim in emphasising the difficulties encountered by the practitioners who are involved in assisted migration projects, both practical and theoretical, is to draw attention to another way of approaching these projects. Analysing assisted migration, as I have done so far in this chapter, as a governmental technique for making flexible and entrepreneurial migrants and re-engineering newly empty or at least fluid space, is only possible if the assumptions guiding the more enthusiastic and interventionist end of the literature spectrum are neither questioned nor tested against what practitioners tell us about the material limits to their practices. Analysing assisted migration as a practice which reproduces and amplifies a certain relationship to space has allowed me to explore it within the parameters laid out by theories of power formations, and to resituate it within the dominant rationality of security and circulation. But as Kay Lewis-Jones has shown in her work on the Millennium Seed Bank, conservation institutions can also be studied as heterotopic spaces in which new formations of plant-human relations are generated and experimented with.[128] When examined in their more relational and speculative dimension, assisted migration proposals seem to foster a potentially reworked relationship to history as well as space, which might add complementary forms of world-making experiments to the hegemonic politics of migrants on unstable ground.

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[126] Maria Hällfors et al., "Addressing Potential Local Adaptation in Species Distribution Models: Implications for Conservation under Climate Change," *Ecological Applications* 26 (1 February 2016), 1154.
[127] Keck, "Avian Preparedness," 344.
[128] See Lewis-Jones, "Holding the Wild," 6.

Here it is useful to adopt another framework for examining this minor mode of assisted migration proposals. I now return to the work of the anthropologist Frédéric Keck, whose scholarship on avian flu preparedness contrasts pastoral techniques of prevention and cynegetic techniques of preparedness as two different and coexisting ways of anticipating and mitigating pandemic risks.[129] His argument in favour of studying biopolitical techniques of security and hunting techniques of semiotic attention and imaginative identification together, tracing how viral preparedness oscillates between the two and how every virological, birdwatching and biosecurity practice can be said to participate in both regimes simultaneously, can be fruitfully applied to conservation biology. Doing so avoids giving too much weight to unilaterally imposed modes of governance and engineering projects, and too little to the minor forms of negotiation and imaginative exercises into which conservationists are led by virtue of their recalcitrant material and its non-generalisable qualities.

In addition to studying the forms of environmental governmentality that can be described by borrowing the parameters of human governance, it is important to present the relations – and this includes asymmetrical and often violent power relations – that are immanent to conservation practices rather than ordered by governmental rationality. As Keck notes, new relations between humans and animals have created new emergences (such as zoonotic disease pandemics), but the very techniques used to mitigate the risks posed by these emergences have also changed human-animal relations in return.[130] An analysis of the mechanisms by which humans manage wildlife can only capture one aspect of these changing relations; complementing it with an exploration of the evolutionary and historical processes conservationists insert themselves into in their varied practices, and the evolutionary and historical roles vis-à-vis their nonhuman experimental partners that they propose to take on, can only enrich a study of the current shifts in the discipline. Conservation biology is a field in which stories are told and cosmologies built, even when its practitioners do not necessarily see themselves as engaging in these processes.

3. Deep Histories

[129] Keck, *Avian Reservoirs*, 173.
[130] Keck, *Avian Reservoirs*, 2.

Model-thinking, as we have seen, is in a deeply precarious position when it comes to assisted migration. This is why the emergence of one particular form of historic example-thinking, mobilised in order to buttress and justify assisted migration projects, is of particular interest. As I have mentioned before, the question of what exactly gets reproduced, or proposed as a model for what conservation biology might become, is far from being a consensual matter. Even those scientists most invested in the novel ecosystems discourse have sometimes noted that "restoration […] must not abandon history entirely," and that "historicity […] will emerge as a new virtue that compels awareness of historical continuities and discontinuities in shaping ecological intervention."[131] The idea that "anything goes" when novel functions are valued above historical baselines has been challenged by the reminder that, even if historical fidelity is not a valued or even attainable goal, path dependence is an important element in ecosystem formation, and that there is an internal logic to the way life forms migrate and assemble even as they are changing.[132]

In this respect, the emergence of a minor but intriguing strand of assisted migration rhetoric grounded in deep-time history and in prehistoric human-aided dispersal functions as a reminder of long-term and large-scale path dependencies in plant movements. This rhetorical shift seems to come as a response to inherent difficulties in sustaining linear progress narratives when confronted with the need for and effects of assisted migration. When I ask her how far the projects she has worked on extend into the future, Hällfors tells me that the usual horizon of current assisted migration modelling is 2050 to 2070; "but of course, it expands even further […] my son, he's probably going to be alive when it's 2100, so that is not too far in the future. […] Because we cannot really anticipate climate change that far, that is where the limits are." She notes that we should be considering the next few hundred years, but also that anticipating anything on that temporal scale is almost impossible given the changes that the next decades are going to bring.[133] Seen in this light, the attempted jump to geo-engineering fantasies – which function as technological proxies for a temporal skip into the future – is one way of linking

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131 Higgs, "Nature by Design," cited in Eric Desjardins, "Historicity and Ecological Restoration," *Biology & Philosophy* 30, no. 1 (1 January 2015): 77–98, 80; Eric Higgs, "Changing Nature: Novel Ecosystems, Intervention, and Knowing When to Step Back," in *Sustainability Science. The Emerging Paradigm and the Urban Environment*, ed. Michael P. Weinstein and R. Eugene Turner (New York: Springer, 2012), 383–98, 390.

132 See Eric Desjardins, Justin Donhauser, and Gillian Barker, "Ecological Historicity, Novelty and Functionality in the Anthropocene," *Environmental Values* 28, no. 3 (1 June 2019): 275–303.

133 Maria Hällfors, interview by author, June 2, 2020.

into this dismembered future. But this rhetoric coexists with new uses of different pasts to justify moving endangered plants, a development which is even more intriguing than the rehashing of techno-utopian scenarios. Rather than pointing to extraterrestrialised futures, the proponents of assisted migration seem to turn to the past as a reservoir of points through which to route plant migrations. And more than that: past references also become pathways to imagining futures, or perhaps rather becomings, that retrace rather than escape, loop rather than progress. This discursive strategy thus runs counter to the idea of absolute contingency and plasticity underpinning the characterisation, examined above, of assisted migration as an engineering project.

Barlow, for instance, has suggested that there is an obvious link between deep-time perspectives, Pleistocene rewilding projects, and assisted migration. In one instance, she argues that:

> A deep-time perspective thus opens up a new line of questioning: where would native range for species X have been during a peak interglacial – or during even more ancient times (species of genus Torreya coexisted with Cretaceous dinosaurs) when global climate was even warmer than it is today? […] A deep-time perspective, penetrating far into the future, invokes a felt urgency for humans to engage in repopulating this continent with megafaunal stock that may eventually re-evolve species truly *native* to this land. This is the ethical ground from which the rewilding proposal ultimately springs.[134]

It is worth noting that when it comes to *Torreya taxifolia*, the palaeoecological argument has been disputed and Barlow's scientific credibility questioned, for example by researchers at the Atlanta Botanical Garden she has corresponded with on the subject.[135] But other scientists have also emphasised the entangled histories of human and nonhuman migrations, suggesting that conservation proposals such as assisted migration could be read as continuous with earlier forms of reciprocal capture and common becomings. According to two anthropologists who have weighed in on the debate, "[h]uman-mediated biological invasions or translocations (intentional or accidental introduction of organisms to new ecosystems by humans) of non-native species by humans have been occurring for at least 20,000 years, with a major

[134] Barlow, "Deep Time Lags", 169-71.

[135] The exchanges in question have been published by Barlow on the Torreya Guardians website; as I have not been able to ascertain if this was done with the consent of her correspondents, I have decided against linking to them here.

acceleration during the Holocene."[136] More recently, Rossetto was among the authors of a paper – the first study of its kind – on the prehistoric assisted migration of plants by Aboriginal people. The authors conclude that:

> Evidence of prehistoric Australian Aboriginal people dispersing plant propagules for their direct need and benefit also significantly challenges assumptions of "natural" plant distributions, requiring reassessment of distributional interpretations that omit the possible impact of prehistoric human intervention. Current debates on the role of human-assisted migration and other active management options could also benefit from the acceptance, from conservation practitioners and the general public, that Aboriginal people deliberately dispersed species in the past. This is particularly relevant since current measures of restoration success are often based on historical (pre-European) reference systems.[137]

In both these accounts, deep-time lags are used as a justification for assisted migration (and Pleistocene rewilding) projects because they transform understandings of what a native range is. Species are not on the move so much as "urged" by changing climate to return to where they came from, the ranges they occupied during the last interglacial period. The idea that, rather than having entered a new phase of their mutation, landscapes have *not yet* adjusted to the loss of megafaunal browsers or are merely a fluke due to "a peak in glacial advance" allows assisted migration to be torqued so that it becomes a technology of stability rather than mobility. Endangered species are coming home rather than escaping; seen in deep time, it is their current position that becomes the anomaly. In appealing to deep time and to intertwined prehistoric migrations, conservationists reactivate the past of spaces, using these pasts as temporal proxies allowing us to see what this particular place *will yet be* like. Appealing to the history rather than the future of migrations in this way is mobilised to justify movement rather than ecosystemic conservatism, in a burgeoning and experimental construction of alternate histories sustaining a variety of speculative futures.

4. Cosmoecological Openings

[136] Courtney A. Hofman and Torben C. Rick, "Ancient Biological Invasions and Island Ecosystems: Tracking Translocations of Wild Plants and Animals," *Journal of Archaeological Research* 26, no. 1 (1 March 2018): 65–115, 66.

[137] Maurizio Rossetto et al., "From Songlines to Genomes: Prehistoric Assisted Migration of a Rain Forest Tree by Australian Aboriginal People," *PLOS ONE* 12, no. 11 (8 November 2017): e0186663, 12.

One could adopt a cynical view and treat this rhetorical shift as propagandist justification, or a hermeneutic one and look for the signs that something these biologists are not aware of is attempting to return in and through their practices. But I argue for supplementing them with a reading of transformative conservation projects as cosmologies or folklore in the making, in which practitioners are constantly oscillating between explicit and conscious rhetorical moves and the effects of those moves, which might exceed their calculations or individual agency. This is why I ask whether accounts of conjoined interspecies migrations could not be read as storied or restoried cosmoecologies.[138] They may not come cloaked in the more immediately foundational (at least in European modernity) guise of pastoral or agricultural relationships of control, care and responsibility, but they may be of use to story indirect forms of learning how to "compose" with others, and of enabling others to compose with new environments. Vinciane Despret and Michel Meuret use the term when talking about long-range transhumance as a way of inhabiting "a space in time," arguing that "to inhabit is at once to be transformed by the environment and to transform it."[139] Recalling deep historical pasts of intertwined migrations also means thinking about different iterations of these techniques for inhabiting spaces in time; as Hofman and Rick remind us, "[p]eople have translocated wildlife for a variety reasons, including for ritual and symbolic purposes, food and subsistence, and/or tool making."[140] Taking such a statement seriously means that the material practices (symbolic, ritual, nutritional) arising from various systems for ordering and understanding the universe have always translated into what could be called ecosystem engineering, or niche creation. And if conservation biology is to be understood variously (or successively) as a set of biopolitical techniques and as a site of cosmopolitical gestures, ought it not also to be treated as one more iteration of cosmologies that attempt to make sense of interspecies relations? Hofman and Rick certainly suggest so. According to them, "[m]odern conservation and restoration practices, such as assisted migration, or the movement of plant or animal populations for conservation purposes, are the latest wave of a continuum of human–environmental management that extends deep into the human past."[141]

[138] See Vinciane Despret and Michel Meuret, "Cosmoecological Sheep and the Arts of Living on a Damaged Planet," *Environmental Humanities* 8, no. 1 (May 2016): 24–36.
[139] Despret and Meuret, "Cosmoecological Sheep," 32.
[140] Hofman and Rick, "Ancient Biological Invasions," 99.
[141] Hofman and Rick, "Ancient Biological Invasions," 99.

I propose to read the deep-time rhetoric of assisted migration proponents as an attempt, as partial, weak or unformed as it may be, to resituate conservation practices into stories of multispecies collaborations, and to remake the stock of examples and images constituting conservationist memory. As Lévi-Strauss notes, in a chiastic movement characteristic of his writing:

> It only seems to me that in societies without writing, positive knowledge fell well short of the power of the imagination, and it was the task of myths to fill this gap. Our own society finds itself in the inverse situation – one leading to the same results though for opposite reasons. With us, positive knowledge so greatly overflows our imaginative powers that our imagination, unable to apprehend the world that is revealed to it, has no other alternative than to turn to myth again.[142]

While he mentions physics as one of the fields greatly outstripping our imaginative powers, and forcing thought to revert back to myth, it is my contention that more grounded disciplines such as biology and ecology are also in the process of confronting emergences on an inhuman scale that are of a similar magnitude, and of responding by an analogous reactivation of structures of thought not neatly confined to scientific practices. Just like Pleistocene rewilding projects, which "imagine and conjure the future return of dislocated and even extinct animals and plants, or their representatives from other regions, and situate these animals and their habitats as themselves productive agents in the process of rewilding," ecological ranges imagined in deep time "present a striking anachronism, strung between the prehistoric and the futural."[143] But unlike the sacrificial underpinning of these rewilding projects, in which nature must be redeemed from humanity itself, assisted migration projects can be read as a means to intercede with catastrophic forces on behalf of a more heterogeneous interspecies collective. By appealing to, recombining, and reinterpreting evolutionary and human history, conservation biologists and ecologists spatialise time in an effort to negotiate with unstable ground and an increasingly risky planet – the shrugging Gaia, the wild country in which feral proliferations have taken over liveable disturbance ecologies. Certain spaces now appear as having been marked as home by previous interspecies

[142] Claude Lévi-Strauss, *The Story of Lynx*, xii. Boris Wiseman, 'Chiastic Thought and Culture. A Reading of Claude Lévi-Strauss', in *Culture and Rhetoric*, ed. Ivo Strecker and Stephen Tyler (New York: Berghahn, 2009), 90.

[143] Matthew Chrulew, "Reversing Extinction: Restoration and Resurrection in the Pleistocene Rewilding Projects," *Humanimalia* 2, no. 2 (2011): 4–27.

collaboration, an argument which also operates a redistribution of life and death by disrupting the sacrificial mechanisms of conservation biology by virtue of which what is invasive and unwanted is treated as if it were already dead.[144] Not being in place no longer necessarily marks plants and animals for death, if their presence in certain ranges can be storied or restoried, and made significant by embedding them into relationships through which they once inhabited these spaces.

What emerges in glimpses in this current repatterning of conservation rhetoric is an understanding of the world that is predicated less on linear trajectories than on temporalities that can be contracted, stitched together, circled back to in cycles much older than the merely seasonal or generational. By calling for a retracing of interglacial movements and prehistoric migration, these endangered plants' pasts *become* their future, a temporal orientation not unlike that of the Yarralin people interviewed by Rose in her *Reports from a Wild Country*. Unlike what she calls the "palindromic" mode of history, inherited from biblical narratives (which she takes as a template for Eurocentric modernity as a whole) and structured around the fulfilment of historical destiny replacing the old with the new, the centrality of the Dreaming in Yarralin temporality is oriented toward origins.[145] In these space-time coordinates, ancestors go before and descendants follow behind them into the Dreaming, always facing the past rather than moving away from it: "people say that 'we here now' are the 'behind mob.' We here now come after or are behind our ancestors who came before us. And the whole of ordinary life can be understood collectively as a 'behind mob' – we all follow along behind the Dreamings."[146]

But drawing such a parallel must come with certain caveats. The examples of deep-time rhetoric I have cited above should not be equated with a call for the return to premodern relations and natures; their authors mobilise prehistoric narratives in the service of contemporary interventions that bear no immediate resemblance to these migrations, and do not contain a clear political potential for questioning how and why these previous relations were destroyed. These shifts in assisted migration discourse should not be taken as a portent announcing the return of conservation biologists to indigenous understandings of time and history, but rather as contemporary attempts at

[144] On the complex mechanisms of purity, sacrifice and violence in conservation, especially when it comes to subjects potentially "compromised" by human intervention, see Hugo Reinert, "Requiem for a Junk-Bird: Violence, Purity and the Wild," *Cultural Studies Review* 25, no. 1 (25 September 2019): 29–40.
[145] Rose, *Reports from a Wild Country*, 55-56.
[146] Rose, *Reports from a Wild Country*, 55-56.

making sense of a shifting environment by rehearsing alternative relationships to time and ways of moving through it. They are certainly taking place in impoverished milieux of the type Stengers describes in her book *In Catastrophic Times*, and to which I will refer again in more detail in the next chapter. Not explicitly designed to foster the emergence of cosmological relations, the experimental plots and seed-collecting expeditions that form the backbone of assisted migration are always open to capture by neoliberal governance and dreams of mastery, even as the practitioners populating these sites attempt to stitch together proto-cosmological narratives with reduced subjects, reduced tools, and reduced concepts. The paucity and promise of these emerging compositions come to a head when conservation biologists turn their gaze on a more richly explored and historically close issue, namely that of domestication processes – a narrative that forms the basis of crop wild relative conservation, and the focus of the next chapter.

Now that we have spoken of the ecological effects rippling out from the modular simplification of the world, I propose to go further, and peer into the space where the fungible bodies making up these simplified plantation ecologies are being revitalised through the recombinant potential of banked wild species. Here we have seen wild species recast as victims, agents, and partners of transformations on a landscape level; the next chapter will go deeper into their mobilisation in the service of another kind of transformation: that of the bodies of their kin. While environmental adversity is seen as a reason for species to move, potentially by reactivating forms of storied interspecies collaborations with humans, in the bodies of crop wild relatives it becomes not so much an obstacle as an opportunity: one which another category of species, those who have co-evolved with humans to the point of domestication, could potentially profit from.

Chapter 3.
"A change in agricultural thinking will be required": Crop Wild Relative Conservation

> "All the beings involved take their very form – the forms of their ways of being and of their modes of action – as so many effects of these connections with other ways of being and of acting."
>
> — Despret, "Traits".

I. Wild Relatives: An Emergent Conservation Concern

1. Banana Clones and Unhoped-for Blooms

"We always tend to fall back on the examples of bananas, because it's one that people can relate to," is Christopher Cockel's answer when I ask him, halfway through the Skype interview we are conducting, how he would describe and locate the urgency of the Crop Wild Relatives Project – the conservation initiative conducted at the Millennium Seed Bank (the largest ex situ wild plant collection in the world, housed at the Royal Botanic Gardens, Kew) which he has led over the past years. Bananas, he reminds me, are a crop currently grown clonally around the world, a peculiarity which transforms these plantations into smooth space for fast-travelling pests. "Because we have grown them clonally for so long, people have moved away from looking at seeded bananas," he continues.[1] What this means is that bananas have effectively become an "orphan crop" of "parthenocarpic, mostly triploid, sterile plant[s],"[2] characteristics which have slowed down research into breeding for more resistant plants. Due to these reproductive and genetic quirks, they have become somewhat of a poster child for the devastating effects of what Tsing calls plantation ecologies, the simplified, modular systems that allowed the feral proliferations we encountered in the previous chapter.[3] The Gros Michel, the main commercial cultivar grown until the 1950s, was entirely wiped out by the Panama disease,

[1] Christopher Cockel, interview by author, August 1, 2018.
[2] J.S. Heslop-Harrison, "Genomics, Banana Breeding and Superdomestication," *Acta Horticulturae*, no. 897 (May 2011): 55–62, 59.
[3] See Tsing, "A Threat to Holocene Resurgence."

a lethal soil-borne fungal wilt; and the same threat is now looming over the Cavendish, the cultivar that replaced it. Collecting and conserving wild banana relatives is emerging as one potential solution to this clonal fragility, which researchers at the Millennium Seed Bank and beyond are hoping to remediate through strategic crossings with more resistant species. But whether there will be time to do so is another question. "We are playing catch-up," Cockel muses: it is not entirely clear when and how the disease will raise its head again, annihilating an entire crop in one biblical strike, and trying to find resistant wild relatives is a race against an unknown and unpredictable deadline.

Bananas, in addition to being an almost perfect illustration of the vulnerability built into the homogenisation of crops in the plantation model that has come to dominate food production in the twenty-first century, also crystallise some of the issues that arise where agricultural and conservationist seed banking overlap. Available seed collections are riddled with gaps: a survey published in 2016 bemoans the dearth of *Ensete* (also known as the Ethiopian banana) accessions in seed banks worldwide,[4] and wild *Musa* relatives – another genus of the banana *Musaceae* family, to which the crops we know as bananas and plantains pertain – are still being assessed for diversity across existing accessions.[5] Another recurring issue with these seeds is the question of the germination process; while most accessions have relatively good success rates, Cockel tells me that the wild bananas collected at Kew currently sit at about thirty percent. Reproducing in the laboratory what species do on their own is fraught with difficulties, especially when it comes to making them amenable to agricultural concerns. Sebastien Carpentier, the bioscience engineer leading the Crop Wild Relatives Project's banana pre-breeding project, has noted that a recent expedition to Papua New Guinea was in part made necessary by the difficulties encountered by his team when it came to regenerating seeds obtained from the Millennium Seed Bank. The rescued sample were neither abundant nor diverse enough, which is why Carpentier and his team returned to the field in order to

[4] "Only one seed bank seemed to hold a seed accession of only one of the three species, *E. ventricosum* (Millennium Seed Bank of the Royal Botanic Gardens, Kew). Available seed accessions of the other two species (*E. homblei*, *E. livingstonianum*) do not seem to exist. The lack of stored seed material of the three *Ensete* species and the difficulties in obtaining fresh seeds make it impossible to use seeds for breeding and crop improvement." (Filippo Guzzon and Jonas V. Müller, "Current Availability of Seed Material of Enset (Ensete Ventricosum, Musaceae) and Its Sub-Saharan Wild Relatives," *Genetic Resources and Crop Evolution* 63, no. 2 (February 2016): 185–91, 185.)

[5] See Yves Bawin et al., "Genetic Diversity and Core Subset Selection in Ex Situ Seed Collections of the Banana Crop Wild Relative Musa Balbisiana," *Plant Genetic Resources: Characterization and Utilization* 17, no. 6 (December 2019): 536–44.

collect more material, among which the most drought-tolerant individuals will be selected for future breeding projects.[6]

This pre-breeding of bananas is made particularly difficult by the general impoverishment of knowledge about the sexual reproduction of these crops, an impoverishment bred alongide simplified crops grown in clonal plantations.[7] Here too, scientists at the Millennium Seed Bank are playing catch-up, trying to characterise the morphology and germination ecology of the plants in their collections.[8] This encompasses every possible aspect of their genotype and phenotype beyond any immediate utility for crop improvement, as I am reminded when our call ends; having gone overtime, we have to cut it short when Cockel remembers a meeting at the greenhouse with colleagues studying flower morphology and who wish to collect recently bloomed banana flowers. The next day, I receive a follow-up email with pictures of the *Ensete livingstonianum* flowers that were successfully collected on the day of our interview; this species, at least, has made itself available enough to some of the concerns of the Kew botanists.[9] But whether these transient blooms will bear seeds for other mobilisations, and enter the category of wild species able to involve themselves with domesticated cousins, is a more precarious matter.

2. Defining Crop Wild Relatives

The wild *Musa* and *Ensete* species Cockel made reference to during our interview fall into the category of crop wild relatives, a term designating species related to currently grown crops. As has been noted by Maxted et al., “each [higher plant species] must to a degree be a crop wild relative”; and the potential of this extensive relatedness is furthered

[6] Sebastien Carpentier, Hunting for Drought Tolerance in Papua New Guinea, 12 November 2019, https://www.cwrdiversity.org/wild-about-bananas/.

[7] While it does not lie within the scope of this thesis, it is worth mentioning here that one could write an interesting and comprehensive agnotology (*sensu* Robert N. Proctor and Londa Schiebinger, eds., *Agnotology: The Making and Unmaking of Ignorance* [Stanford: Stanford University Press, 2008]) of agricultural and conservation science, in the form of a comprehensive overview of the knowledge – both that of humans about the plants they are propagating and nurturing and that of the plants themselves – lost or made impossible in ex situ *dispositifs*. On the topic of banana reproduction, Tamrat et al. have recently attempted to regain some of the knowledge elided by or lost in intensive clonal propagation (Solomon Tamrat et al., “Germination Ecology of Wild and Domesticated Ensete Ventricosum: Evidence for Maintenance of Sexual Reproductive Capacity in a Vegetatively Propagated Perennial Crop,” *BioRxiv*, preprint, May 2 2020).

[8] See for example Tamrat et al, “Germination ecology of *Ensete ventricosum*.”

[9] Christopher Cockel, personal communication, August 2, 2020.

by recent technological advances in genetic engineering methods, in light of which "most if not all species are potential gene donors to a crop."[10] But when it comes to setting conservation priorities, be they in or ex situ, such a definition will not do, and there have been repeated efforts over the past decades at constituting a pragmatic definition of a crop wild relative that could guide the setting of conservation targets and priorities. Drawing on the writings of Nikolai Vavilov, who first developed the concept of centres of origin of cultivated plants in the 1920s, Harlan and de Wet proposed a de-taxonomised definition of crop wild relatives in 1971. Vavilov, whose work predates molecular genetics, formalised what he called the Law of Homologous Series in order to systematise parallel patterns of variations between domesticated and wild crops across different species, and this law still has predictive value when it comes to identifying certain desirable traits in crop wild relatives.[11] Harlan and de Wet formalised some of Vavilov's views in their attempt to arrive at a "rational classification of cultivated plants" in 1971, in which they argued that formal taxonomy has proven an inconsistent and confusing grid for understanding and working with cultivated crops, leading geneticists, agronomists, horticulturalists and foresters to develop their own informal classification systems based on intuition and embodied familiarity.

According to Harlan and de Wet, "cultivated plants *are* different from wild ones and require special taxonomic treatment," given their emergence under strong and "biologically capricious" selection pressures which result in the propagation of biologically monstrous cultivars in an environment that is "artificial, unstable and often very extensive geographically."[12] This proliferation of artificiality has prompted what Harlan and de Wet see as a taxonomic inflation that is of very little use to those who have to work directly with cultivated plants; their goal is not to add more formal botanical categories to contentious lists and thus to pin down slippery species ontologies, but to provide a dynamic and flexible method for understanding how genes can flow between species. Breeders need to know what species *can do* rather than what they *are*.

The gene pool concept developed in this highly influential article divides the potential pool of genetic material available for the transformation of a given crop into

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[10] Nigel Maxted et al., "Towards a Definition of a Crop Wild Relative," *Biodiversity and Conservation* 15, no. 8 (July 2006): 2673–85, 2674 and 2676.

[11] See Nikolai I. Vavilov, "The Law of Homologous Series in Variation," *Journal of Genetics* 12, no. 1 (1 April 1922): 47–89, and Maxted et al., "Towards a Definition of a Crop Wild Relative," 2675.

[12] Jack R. Harlan and J. M. J. de Wet, "Toward a Rational Classification of Cultivated Plants," *Taxon* 20, no. 4 (1971): 509–17, 509.

three categories according to ease of hybridisation and fertility of offspring. The primary gene pool overlaps with the concept of biological species, which includes "spontaneous races (wild and/or weedy) as well as cultivated races," which cross easily with each other and produce fertile hybrids; the secondary gene pool contains all the species that will breed with the crop, even though species barriers might make it difficult and hybrids are not always viable, and some effort must be exerted in order to bring these crosses about ("the gene pool is available to be utilized, however, if the plant breeder or geneticist is willing to put out the effort required"); the tertiary gene pool defines "the extreme outer limit of potential genetic reach," and contains species which might be crossed with the crop only if extreme techniques such as embryo culture or grafting (and now genetic modification technologies) are used to do so.[13]

The most widely used version of the gene pool concept in the current literature on crop wild relatives is the one recently augmented by Maxted et al. by pairing it with a taxonomic model in order to allow the establishment of crop wild relative conservation priorities in the absence of data on actual hybridisation and genetic diversity. Taxonomy, while still noted to be inconsistent, nevertheless has practical uses when trying to estimate genetic distance and relationships. The authors of this paper propose, as a conclusion of their synthesis, a much-cited working definition of crop wild relatives: "A crop wild relative is a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR [crop wild relative] belonging to Gene Pools 1 or 2, or taxon groups 1 to 4 of the crop."[14] I will come back later to the biological uncertainties and classificatory attempts generated by the use of crop wild relatives; the taxonomic literature on the topic is a first indication that what is at stake here is defining and policing the space in which species meet and enter into genealogical relationships. As we will see in the last section of this chapter, those relationships exceed the neat classification of gene pools or taxon groups, requiring scientists to rethink the position of domesticates as well as those of wild relatives.

3. Histories of Crop Wild Relative Use

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[13] Harlan and de Wet, "Toward a Rational Classification", 511-12.
[14] Maxted et al., "Towards a Definition", 2680

As definitions relying on previous crossing experiments – such as the gene pool concept – signal, the use of crop wild relatives in agriculture is not an entirely new occurrence. Christine and Robert Prescott-Allen, for instance, date the European version of this practice back to at least the nineteenth century.[15] Its development over the last two centuries is intimately linked to the intertwined trajectories of extractive colonialism, the bio- and geographical upheaval it represented for many nonhuman species in addition to human populations, and the specific mode of management and generation of surplus value that is the plantation and its "simplified ecologies," exemplified by the cultivation of sugar cane.[16] This model was expanded to most of our current food production systems, now constituted almost exclusively by these "machines of replication," monocrops intensely vulnerable to the globalised fluxes of pests and pathogens and responsible for the formation of the "new Pangaea" I mentioned in the previous chapter.[17] One of the earliest recorded commercial uses of wild relatives occurred in North American wine grape cultivation in order to combat the grape phylloxera, a sap-sucking insect that bores into vine roots and infects them with poison in the process. Originally native to North America, it was dispersed through botanical specimens collected in the 1850s.[18] While direct hybridisation with native American vines was researched and implemented at the time, it did not produce commercially viable grapes in terms of aroma, a problem remediated when the entomologist Charles Valentine Riley developed the use of resistant rootstock for grafting. Most of the wines we drink are now produced from grafted stock, with the exception of a few scattered vineyards throughout the world that have miraculously escaped the blight, for reasons that have not yet been fully elucidated.[19]

Another more violent intersection of vegetal and animal vulnerabilities, and one with more far-reaching socio-political and population-geographical consequences, was the late blight epidemic that ravaged most European potato cultivars in the nineteenth

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[15] Christine Prescott-Allen and Robert Prescott-Allen, *The First Resource: Wild Species in the North American Economy* (New Haven: Yale University Press, 1986), 276.

[16] On the origin and expansion of plantation ecologies, see for instance Sidney W. Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York: Penguin Books, 1986) and Jill H. Casid, *Sowing Empire: Landscape and Colonization* (Minneapolis: Minnesota University Press, 2005). For a concise summary of sugar cane plantations as rehearsal sites for modernity, see A. L. Tsing, "On Nonscalability: The Living World Is Not Amenable to Precision-Nested Scales," *Common Knowledge* 18, no. 3 (1 October 2012): 505–24.

[17] See Scheele et al., "Amphibian Fungal Panzootic."

[18] Marta Macedo, "Port Wine Landscape: Railroads, Phylloxera, and Agricultural Science," *Agricultural History* 85 (1 April 2011): 157–73.

[19] See Patrice This, Thierry Lacombe, and Mark R. Thomas, "Historical Origins and Genetic Diversity of Wine Grapes," *Trends in Genetics* 22, no. 9 (September 2006): 511–19.

century; having spread from Mexico all through the United States, it followed trade routes and arrived in Europe on a potato shipment bound for Belgium in 1845. Late blight still is one of the most destructive potato diseases to date (and, in yet another twist of second-millennium militaristic ironies, was investigated for a while as a possible biological weapon in crop warfare).[20] The epidemic prompted research into cross-breeding possibilities, and resistance to late blight was discovered in a wild Mexican potato species, *Solanum demissum*, albeit with limited success, since the pathogen was able to overcome the newly bred resistance through mutations.[21] Another wild species, *Solanum fendleri*, is still used in breeding to protect against nematodes;[22] generally speaking, wild potato relatives have been used in commercial breeding for over 150 years. Similarly, at yet another lethal crossroads of colonialism, capitalism and nutritional desires, sugar cane crops have been improved by the use of crop wild relatives in the first half of the twentieth century.[23] And the bitter end of the colonial taste spectrum is well-represented too: coffee wild relatives, the potential saviours of an endangered industry, are one of the Millennium Seed Bank's preferred examples when it comes to public communication about the project, illustrating Kew's implication in economic colonial botany and its "transformation from a colonial institution that governed 'nature' and colonies alike, to an institution that is increasingly implicated in the governance of biodiversity."[24]

While these examples of wide-ranging and commercial uses of crop wild relatives go back much further, they still amount to what Reem Hajjar and Toby Hodgkin call only "a handful of crop success stories." The use of crop wild relatives only truly rose to prominence in the 1970s and 1980s, which is also the period in which both ex situ conservation (and seed banking in particular) was developed as a stronger component of the conservationist agenda, and ex situ institutions started to switch over to conservation

[20] See Paul Rogers, Simon Whitby, and Malcolm Dando, "Biological Warfare against Crops," *Scientific American* 280, no. 6 (1999): 70–75.

[21] See Agim Ballvora et al., "The R1 Gene for Potato Resistance to Late Blight (Phytophthora Infestans) Belongs to the Leucine Zipper/NBS/LRR Class of Plant Resistance Genes," *The Plant Journal* 30, no. 3 (May 2002): 361–71.

[22] See Charles Brown, Hassan Mojtahedi, and J. Bamberg, "Evaluation of Solanum Fendleri as a Source of Resistance to Meloidogyne Chitwoodi," *American Journal of Potato Research* 81 (1 November 2004): 415–19.

[23] See Reem Hajjar and Toby Hodgkin, "The Use of Wild Relatives in Crop Improvement: A Survey of Developments over the Last 20 Years," *Euphytica* 156, no. 1–2 (21 May 2007): 1–13.

[24] Neves, *Postnormal Conservation*, 68.

activities and discourses.[25] Picking up where the survey by the Prescott-Allens leaves off, Hajjar and Hodgkins have written a comprehensive overview of developments in crop wild relative use between 1980 and 2005 in nineteen crops (rice, wheat, maize, barley, sorghum, millet, cassava, potato, chickpea, cowpea, lentil, soybean, bean, pigeonpea, banana, groundnut, tomato, sunflower and lettuce); the survey focuses on the development of new cultivars incorporating genes from wild relatives, which the authors trace in thirteen of the aforementioned crops.[26] Crop wild relatives, during this period and for these major crop species, have been overwhelmingly used in order to pass on traits pertaining to pest and disease resistance; the authors identify a small handful of crop wild relatives used to remedy abiotic stress, but these decades were mostly dominated by demands for increased agricultural productivity (rather than a problematisation of the survival of agriculture itself, as we will see in a moment) and the devastating biotic interplays bred into crop monoculture, and by the question of how to remediate them.

The many historical examples I have sketched out here link back to Harlan and de Wet's observation that "the germ plasm of domesticated plants has been repeatedly and periodically stirred" by "repeated introductions or migrations, followed by natural or artificial hybridizations."[27] Domestication, especially of plant species, is never a linear nor a completed progress – a fact clearly illustrated by the multiple introductions that have braided crop wild relatives back into agricultural history. This non-linearity of domestication processes is one of the aspects of crop wild relative conservation that I will explore in this chapter; just as assisted migration replays historical narratives drawn from the Cretaceous or the Palaeolithic, crop wild relatives are enrolled into discursive re-enactments of historically located practices.

4. Crop Wild Relatives at the Millennium Seed Bank

Crop wild relatives, as shown in the accounts of their historical significance, have proliferated at the physical and institutional edges of agriculture for a long time. But now,

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[25] See Erich Hoyt and Susanah Brown, *Conserving the Wild Relatives of Crops* (Rome: International Board for Plant Genetic Resources, 1988). On the turn of institutions such as zoos and botanic gardens to conservation, see Donahue and Trump, *The Politics of Zoos*.

[26] See Hajjar and Hodgkin, "The Use of Wild Relatives."

[27] Harlan and de Wet, "Toward a Rational Classification," 510.

it seems like a decisive threshold has been crossed when it comes to the uses of crop wild relatives, and the scale of their conservation. The issue today is not only the mobilisation of wild relatives to manufacture resistance to occasional and evolving biotic stresses; it is to fold the genetic resources of the wild into the wider project of adapting agriculture to climate change, a catch-all term encompassing a variety of biotic and abiotic stresses caused by destructive human interventions into the climate. This unified search for climate change mitigation, the "future-proofing," perhaps, of not only isolated crop species but of a socio-economic system as a whole, has crystallised relatively recently around a project initiated in 2011: "Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives," also known and commonly referred to as the Crop Wild Relatives Project. It was launched to the tune of USD50 million in funding provided by the Norwegian government (notable for its involvement in fossil fuel exports and humanitarian aid both). It is managed by the Crop Trust in partnership with the Royal Botanic Gardens, Kew, which houses the Millennium Seed Bank, and carried out in collaboration with various gene banks and breeding programs around the world.[28]

The collecting phase of the Crop Wild Relatives Project was supposed to finish by the end of 2018, which is when I conducted my first interview with Cockel. At the time, he told me that it would last a year longer to wrap up all the ongoing expeditions – and, of course, the research and breeding projects conducted with the newly availabe accessions will extend long past the end date of the first phase. The project includes twenty-four partner countries, each conducting their own collection expeditions and keeping half the collected seed in their national agricultural seed banks. The other half of the collections, along with miscellaneous biological material and metadata such as accession vouchers, is dispatched to the Millennium Seed Bank. From there, the seeds are sent on to partner gene banks specialised in working with particular crops (such as the International Center for Agricultural Research in the Dry Areas [ICARDA] or the Banana Transit Centre), which regerminate and mutiply those accessions, as the original sample sizes are not sizeable enough for use in hybridisation projects. This phase of the project is now moving into the pre-breeding phase, during which partner institutions cross crops

[28] See Hannes Dempewolf et al., "Adapting Agriculture to Climate Change: A Global Initiative to Collect, Conserve, and Use Crop Wild Relatives," *Agroecology and Sustainable Food Systems* 38, no. 4 (21 April 2014): 369–77.

with wild relatives, grow out the resulting hybrids, and monitor the different characteristics and traits they exhibit, and which might endow crops with vital resistances. As Cockel tells me, this distribution of partners and sites is a continuation of a structure already in place, as the Millennium Seed Bank already relied on a network of coordinators stationed in various countries before the project was implemented.[29]

The reason why I examine the Crop Wild Relatives Project as an exemplar of contemporary shifts in wild plant use is because it is notable both for its scope and its stated goal, as well as the sense of widely distributed urgency it communicates. In the words of Cary Fowler – writing about the Global Crop Diversity Trust and the Svalbard Global Seed Vault, a few years before the Crop Wild Relatives Project would be implemented:

> Crop varieties will not simply follow the thermometer. Seeds of current varieties will not simply be put on a plane or truck and transported to areas with more familiar temperatures. Changes in photoperiod alone will prevent such a straightforward response in many cases. Crops will have to adapt to fit new and different growing conditions and environments; temperature being but one factor.[30]

This quote speaks to a significant shift in focus when it comes to the goal of crop wild relative utilisation. Unlike a spot-treatment maintenance of individual crop species, which is what wild relatives have historically been used for, the issue now is a global threat to the very makeup of global agricultural systems. Just like it makes the historical distribution ranges of wild species obsolete (as we have seen in the previous chapter), climate change is prompting agriculturalists and biologists to think about the resilience of agriculture as a biosocial system. Large-scale projects such as the creation of the Svalbard Global Seed Vault and the Crop Wild Relatives Project are strategic responses to this emerging need to "climate-proof" or "future-proof" this system.[31] This admittedly lofty aim is what propels the Crop Wild Relatives Project to the status of a concerted intervention into interspecies relations. It simultaneously highlights the many pre-existing negotiations across the domesticated-wild border that have taken place

[29] Christopher Cockel, interview by author, August 1, 2018.

[30] Cary Fowler, "Crop Diversity: Neolithic Foundations for Agriculture's Future Adaptation to Climate Change," *AMBIO: A Journal of the Human Environment* 37, no. sp14 (November 2008): 498–501, 500.

[31] "Climate-Proofing Our Food with Crop Wild Relatives," Crop Trust, 22 April 2020, https://www.croptrust.org/blog/climate-proofing-our-foods-with-crop-wild-relatives/ and "Future-Proof the Chickpea," 6 July 2019, https://www.cwrdiversity.org/22665/.

throughout agricultural history, and inserts the scientists and breeders involved in the project into the continuity of these negotiations.

Scaled up, well-funded, and high-profile, this project is also an exemplar of a recent convergence between agricultural and conservationist concerns. Agricultural gene banks have existed for several decades, and have been crucial in shaping agriculture as we know it now (as Helen Curry has shown in her historiography of the Rockefeller Foundation).[32] More specifically, the conservation of crop wild relatives has been underway for several decades in gene banks pertaining to the CGIAR, a prominent international agricultural research partnership.[33] While the systematic conservation of crop wild relatives is therefore not an unprecedented practice, this institutional migration must be analysed as a new strategic development with potential ontological implications.

Seed banks held in botanic gardens, in fact, have recently come under scrutiny as potential allies for agricultural concerns. In the past two decades, several scientists have attempted gap analyses of crop wild relative accessions in seed banks and called for a stronger involvement of botanic gardens in crop wild relative conservation, on the basis that the underutilised crop wild relative accessions distributed across botanical gardens form a potentially robust complement to agricultural seed bank accessions. Meyer and Barton, for instance, state that "botanic gardens maintain 22 global priority and 108 US priority CWR taxa not reported by crop gene banks. A combination of crop gene bank and botanic garden holdings results in broader taxonomic coverage."[34] The general consensus is that the accessions held by botanical gardens are crucial but of poor quality and limited usefulness in their current state. One survey done in 2018 still states that "it is essential that botanic garden collections be of sufficient quality and quantity to ensure that they are of use. In terms of conserving PGRFA [plant genetic resources for food and agriculture], botanic gardens will never match the scope of the large gene banks of

[32] See Curry, "From Working Collections."

[33] "A search on the SINGER database of CG gene banks shows that since Plucknett et al.'s 1987 study documenting wild accessions in international agricultural research centers, absolute numbers of wild accessions, as well as the percent of wild species accessions per crop, have increased substantially […]. Almost all of the crops reviewed here have hundreds, or thousands, of wild species accessions held just in the international genebanks of the CGIAR and many more accessions are often held in national genebanks." (Hajjar and Hodgkin, "The Use of Wild Relatives," 9.)

[34] Abby Meyer and Nicholas Barton, "Botanic Gardens Are Important Contributors to Crop Wild Relative Preservation," *Crop Science* 59, no. 6 (November 2019): 2404–12, 2404.

cultivated plants."[35] This discrepancy can be explained by a history of increasing specialisation in botanical science, ultimately leading to applied plant breeding and botanical science being managed separately. The former has been historically conducted at gene banks and guided by national food and agriculture policies, and the latter confined to botanical gardens, often with the goal of fulfilling environmental targets such as those set by the Convention on Biological Diversity in the Global Strategy for Plant Conservation.[36] I will come back later to the significance of this divide, and to the ways in which crop wild relatives bridge these divergent regimes of use, knowledge and management.

The prominence and scale of this project sets the Crop Wild Relatives Project apart from previous attempts at bringing together conservationist and agricultural agendas. Its significance is threefold: this new convergence has the potential to transform existing collections, to change the nature of wildlife conservation projects (and therefore of institutions such as the Millennium Seed Bank), and finally to question the very structure of agricultural systems prevalent in industrialised countries.

The transformative effects on collections themselves have to do with the gap analyses I have just mentioned, and to which the Crop Wild Relatives Project is seen as a response; it is sometimes held up as "an exceptional example of a botanic garden providing focused support for CWR preservation," fulfilling the oft-celebrated "potential for additional collaboration and alignment of CWR preservation by the global crop gene bank and botanic garden communities."[37] Such an enrolment of botanic gardens in crop wild relative conservation in the name of "complementarity, redundancy, and synergy"[38] will necessarily shape the development of conservation biology in the years and decades to come. The Millennium Seed Bank was established from the outset with an instrumental goal in mind, namely to "[make] its seed collections, scientific information, and expertise available to organizations involved in researching and delivering innovative solutions in agriculture, horticulture, forestry, habitat restoration, and other industries," but the Crop

[35] Katherine O'Donnell and Suzanne Sharrock, "Botanic Gardens Complement Agricultural Gene Bank in Collecting and Conserving Plant Genetic Diversity," *Biopreservation and Biobanking* 16, no. 5 (October 2018): 384–90, 390.

[36] See Ruth J. Eastwood et al., "Conservation Roles of the Millennium Seed Bank and the Svalbard Global Seed Vault," in *Crop Wild Relatives and Climate Change*, ed. Robert John Redden et al. (John Wiley & Sons, Ltd, 2015), 173–86.

[37] Meyer and Barton, "Botanic Gardens Are Important Contributors," 2408 and 2405.

[38] Erin Coulter Riordan and Gary Paul Nabhan, "Trans Situ Conservation of Crop Wild Relatives," *Crop Science* 59, no. 6 (1 November 2019): 2387–2403, 2398.

Wild Relatives Project is expected to foster even stronger "synergies for both wild and domestic plant diversity conservation."[39]

The transformative potential of crop wild relative conservation also seems to expand beyond conservation, as it responds to a wider structural issue in agriculture. Brummer et al. diagnose the challenge and the potential solution thus:

> Agricultural plant breeding is typically commodity- or species-oriented and solves problems within a species, rather than making breeding choices based on systemwide needs. […] If environmental harmony is, in addition to food security, to be a key breeding objective, then a change in agricultural thinking – to appropriately value whole cropping systems – will be required; this is something the public sector is well positioned to do.[40]

As a counterpoint to this optimistic assessment, Maywa Montenegro de Wit proposes a critical reading of the economic interests underpinning the emergence of crop wild relative conservation in new institutions, a tendency she analyses as characteristic of a renewal of primitive accumulation. According to Montenegro de Wit, the celebrated complementarity of agricultural and conservationist approaches mean that "conservation and breeding science are co-evolving to extend seed commodity relations into new spheres," and are complicit in dispossessing local populations and reshaping upstream conservation priorities to suit economic agendas.[41] The up- and downstream pressures exerted by the emergence of a new category of species to be conserved has consequences on wildlife conservation in its entirety, shaping both the structure of the institutions in which these species are collected, stored and studied, and their aims and mandates when it comes to participating in forms of seed enclosure.

Whichever level of crop wild relative conservation one chooses to focus on, it seems clear that its transformative potential could translate into significant and powerful effects for conservation biology as a discipline and for the heterogeneous crew of nonhuman partners pulled into conservation projects, some of which are explored in this chapter. I will start by examining what changes in the discursive presentation of endangered wild species when crop wild relatives are being evaluated and defined in

[39] Eastwood et al., "Conservation Roles," 176.

[40] E. Charles Brummer et al., "Plant Breeding for Harmony between Agriculture and the Environment," *Frontiers in Ecology and the Environment* 9, no. 10 (December 2011): 561–68, 566.

[41] Maywa Montenegro de Wit, "Stealing into the Wild: Conservation Science, Plant Breeding and the Makings of New Seed Enclosures," *The Journal of Peasant Studies* 44, no. 1 (2 January 2017): 169–212, 169.

relation to their domesticated counterparts rather than other wild species. What appears in this new discursive formation is a variable understanding of vulnerability and strength, and a relocation of resilience or resistance into the space of what happens or may happen between individuals and species. This relocation, and the restructuring of the conservationist discourse it brings about, is tied to the fact that crop wild relative conservation brings back together two regimes of knowledge and activity – conservation and agriculture – that had been developing in parallel for decades, disrupting entrenched understandings of wild and domesticated species and well-rehearsed modes of relating to them. These observations then lead me to explore what exactly is being created in this space between species once crop wild relatives are collected and pre-bred, and to qualify the new sets of interactions constructed or made possible in experimental breeding stations as a specific kind of interspecies *achievement*. This achievement, however – the re-involvement into each other's genealogies of relatives often separated by globalised commodity flows and divergent co-evolutionary histories – is arrived at in a singularly impoverished milieu. In this context, the speculative production of who or what various nonhuman species can relate to is recuperated and flattened into an abstract and commodifiable matter of genomics. And while a study of the achievements obtained in the seed bank and the laboratory is an important element in analysing how crop wild relatives reconfigure contemporary conservation biology, it is equally crucial to resituate these practices into their wider milieu, a milieu in which scientists lack resistance to the enslaving power of capitalism.[42]

This leads me to inquire into the other cosmological gestures performed in this project, and to the worlds they constitute. The scientists involved with crop wild relative conservation seem increasingly led to adopt attitudes more akin to hunting than to controlled laboratory practices in their attempts to understand what these plants can do for currently used crop species. Describing these attitudes, and the pressures under which conservation biology is transforming, will ultimately lead me to discuss the significance of crop wild relative conservation for the history of domestication, or rather the contemporary multiplication and re-enactment of alternative *histories* of domestication in conservationist discourses and practices.

[42] See Stengers, *In Catastrophic Times*, 72-3.

II. Multiple Regimes and Relational Attributes

1. Vulnerability and Resilience

Foregrounding relations to crop species as a new category through which to evaluate collection and conservation priorities has exerted a rippling effect on the discourse framing the particular group of wild species thus singled out. Once they are collected and conserved with a view to fulfilling an agricultural goal, crop wild relatives are no longer evaluated in relation to other endangered wild species or as part of wild collections only; they are characterised in contrast to their domesticated cousins, a discursive framing which emphasises not only the vulnerability of wild species – the rhetoric which informs most large-scale ex situ projects[43] – but also a newly defined strength or resilience.

This gives rise to an oddly patchy discourse, traceable throughout the literature on crop wild relative conservation. Projects for conserving crop wild relatives, in particular those conducted in botanical gardens rather than in a purely agricultural setting, are framed in terms that oscillate constantly between vocabularies of sturdiness and fragility. One the one hand, crop wild relatives are recast as a reservoir of diverse traits, as they "have been exposed to selection in their native range and retain a high degree of genetic diversity."[44] This history of selection is what ties genetic diversity to resilience, the latter producing the former as a result of accumulated environmental hardships:

> However, considering the diverse interactions between crops and environmental factors, it is surprising that evolutionary principles have been underexploited in addressing these food and environmental challenges. Compared with domesticated cultivars, crop wild relatives (CWRs) have been challenged in natural environments for thousands of years and maintain a much higher level of genetic diversity.[45]

[43] On this topic, see for instance Mounce, "Ex Situ Conservation of Plant Diversity" and Diana J. Pritchard et al., "Bring the Captive Closer to the Wild: Redefining the Role of Ex Situ Conservation," *Oryx* 46, no. 1 (January 2012): 18–23.

[44] Laura V. S. Jennings, "Creating Guides for Seed Collectors," *Royal Botanic Gardens Kew* (blog), n.d., https://www.kew.org/read-and-watch/crop-wild-guides-for-seed-collectors.

[45] Hengyou Zhang et al., "Back into the Wild – Apply Untapped Genetic Diversity of Wild Relatives for Crop Improvement," *Evolutionary Applications* 10, no. 1 (January 2017): 5–24, 5.

Crop wild relatives are often opposed to domesticated plants, which are sometimes described as "pampered" and as having lost the ability to survive outside of human care (a trade-off allowing for more intense flourishing and yielding as long as they remain in that care).[46] The vulnerability of crop species springs precisely from the process of domestication, which is seen as having reduced their ability to respond to novel threats such as drought, salinity and pests.[47] Jian Lu et al. also hypothesise that the "cost of domestication" is the accumulation of deleterious mutations hitched to the genes selected for during breeding, a process which ultimately leads to genetic bottlenecks.[48] The particular type of resilience specific to crop wild relatives sometimes even becomes an argument for their conservation in situ rather than ex situ:

> Simply hoarding CWR in gene banks is not the complete answer as it halts the evolutionary process and the emergence of new genetic traits, an essential process given the uncertainty about what climatic and production environments we will face in the future.[49]

The value of crop wild relatives lies not only in the set of traits they may contain at the moment of collection and pre-breeding, but in the possibility of a continued relation with a changing and dangerous environment, which they are nevertheless better equipped to survive than crop species.

But, of course, the Crop Wild Relatives Project would not have seen the light were it not for the following peculiarity: that these superlatively resilient plants, whose biographies of adversity encapsulate salvation for our pampered crops, also participate in regimes of extreme fragility. Their endangerment is double, and takes place both inside and outside of the seed bank. In situ, crop wild relatives are still exposed to the same environmental threats as their agriculturally unusable companions. While they are not composed exclusively of species listed in critical Red List categories, their projected extinction rate forms the basis of many calls for increased crop wild relative conservation.

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[46] "A Global Rescue Safeguarding the World's Crop Wild Relatives" (The Crop Wild Relatives Project), accessed 4 December 2020, https://www.cwrdiversity.org/wp/wp-content/uploads/2019/12/A-Global-Rescue-Safeguarding-the-Worlds-Crop-Wild-Relatives.pdf.

[47] See for instance Shyam Singh Yadav et al., "Impact of Climate Change on Agriculture Production, Food, and Nutritional Security," in *Crop Wild Relatives and Climate Change*, ed. Robert John Redden et al. (John Wiley & Sons, Ltd, 2015), 3.

[48] See Jian Lu et al., "The Accumulation of Deleterious Mutations in Rice Genomes: A Hypothesis on the Cost of Domestication," *Trends in Genetics* 22, no. 3 (1 March 2006): 126–31.

[49] Yadav et al., "Impact of Climate Change," 14.

Dempewolf et al., for instance, note that "[u]p to 75% of these species may be threatened in the wild, and climate change is projected to impose further pressures," and Jarvis et al. have modelled projected impacts of climate change on the wild relatives of three crop species, finding that up to twenty percent of them would go extinct and most of them lose half their range size by 2055.[50] As for ex situ vulnerability, Dempewolf et al. note that "[i]nternational efforts in collecting plant genetic resources in general have been in decline in recent decades. Wild species are widely thought to be under-represented in ex situ collections at 2–18% of total holdings"; as I mentioned in the previous section, the Crop Wild Relatives Project itself is a response to perceived structural weaknesses of current ex situ conservation efforts.[51]

What we see emerging in this conservation project is a fluid and sometimes contradictory characterisation of the two categories of species to be managed, kept alive, and interbred. Crop wild relatives are resilient because they are so very good at surviving harsh conditions on their own, which separates them from domesticated species while at the same time providing the locus of their potential salvation. Yet they are also endangered as wild species, because their acquired resilience is nevertheless not enough to get them through the accelerated changes wrought by human-induced climate change – conditions which, even though they now affect crop species, are much less immediately destructive for them. Crop wild relatives thus tack back and forth between different ways of being endangered: crops are vulnerable because too well adapted to industrialised societies, crop wild relatives because they are too little; crops are resilient because managed in the violent care of human supervision, and crop wild relatives because they have been able to test their mettle against a variety of environmental threats undisturbed.

In this gap between wild and domesticated endangerments new relationships emerge, redefining what endangerment is and how it is to be mitigated. Life, meaning, evolutionary relationships circulate in rich, lively and often violent ways when we look at what happens between the conservation of wild and domesticated species. Trying to characterise more specifically what different regimes of extinction and resilience are at

[50] Dempewolf et al., "Adapting Agriculture to Climate Change," 371 and see Andy Jarvis, Annie Lane, and Robert J. Hijmans, "The Effect of Climate Change on Crop Wild Relatives," *Agriculture, Ecosystems & Environment* 126, no. 1–2 (June 2008): 13–23. See also Jesús Aguirre-Gutiérrez et al., "Crop Wild Relatives Range Shifts and Conservation in Europe under Climate Change," ed. Tomas Vaclavik, *Diversity and Distributions* 23, no. 7 (July 2017): 739–50, and Brian V. Ford-Lloyd et al., "Crop Wild Relatives – Undervalued, Underutilized and under Threat?," *BioScience* 61, no. 7 (July 2011): 559–65.

[51] Dempewolf et al., "Adapting Agriculture to Climate Change," 374.

play in this particular instance of conservation might go some way towards giving a little more texture to what Baptiste Morizot calls the "accountant's tricks" of the term biodiversity, which "erases any distinction between wild, domestic, and synanthropic."[52] Crop wild relative conservation has the potential to articulate the concept of wilderness and its complicated political baggage with emerging inquiries into domestication, "in the hope that the 'domesticated' will no longer be treated as the unmarked, unproblematic categorial opposition to the complex and powerful notion of the wild."[53] Crop wild relative conservation is one domain where *both* these categories come to be problematized through this constitutive move between registers.

2. Biopolitical Regimes

The categorial fluidity of the plants managed in the Crop Wild Relatives Project draws attention to the coexistence of multiple biopolitical regimes that characterises many interspecies interactions. This idea has been developed in a range of recent scholarship drawing on and extending Foucauldian theories of power to interrogate the production and management of nonhuman lives.[54] Jamie Lorimer and Clemens Driessen, in their work on "bovine biopolitics," have drawn attention to the different regimes that cattle – a "model organism" for animal studies – can be subjected to depending on which actors and whose agenda they are enrolled in. The list comprises the domains of agriculture, conservation, animal welfare and biosecurity, to which the authors add the novel biopolitical logic of rewilding projects. Each instance of biopolitical objectification and subjectification constitutes cattle according to different aims, targets, and logics, and in the process creates various differing ideals (efficient protein producers, hardy heritage breeds, happy cows, predictable systems) as well as monstrous counter-ideals (both

[52] Baptiste Morizot, "Le Devenir Du Sauvage à l'anthropocène," in *Comment Penser l'Anthropocène?*, ed. Rémi Beau and Catherine Larrère (Paris: Presses de Sciences Po, 2018), 251 (my translation).

[53] Rebecca Cassidy, "Introduction: Domestication Reconsidered," in *Where the Wild Things Are Now: Domestication Reconsidered*, ed. Rebecca. Cassidy and Molly H. Mullin (Oxford, New York: Berg, 2007).

[54] This strand of scholarship includes, for instance, Timothy W. Luke, "The Missouri Botanical Garden: Reworking Biopower as Florapower," *Organization & Environment* 13, no. 3 (1 September 2000): 305–21; Eric Darier, ed., *Discourses of the Environment* (Oxford: Blackwell, 1999); Lewis Holloway and Carol Morris, "Contesting Genetic Knowledge-Practices in Livestock Breeding: Biopower, Biosocial Collectivities, and Heterogeneous Resistances," *Environment and Planning D: Society and Space* 30, no. 1 (1 January 2012): 60–77; Hugo Reinert, "The Care of Migrants: Telemetry and the Fragile Wild," *Environmental Humanities* 3, no. 1 (1 May 2013): 1–24; Matthew Chrulew and Dinesh Wadiwel, *Foucault and Animals* (Leiden, Boston: Brill, 2017); Bierman and Mansfield, "Biodiversity, Purity, and Death"; Lorimer, *Wildlife in the Anthropocene*; Neves, *Postnormal Conservation*.

human and nonhuman), in the process constituting what the authors call a teratology - "the study of abnormality and the ways in which it is defined, governed and rendered affective as monstrous."[55] Lorimer and Driessen's investment in the promissory potential of monsters, inherited from Haraway's exploration of cyborg subjects of technobiopower, is not entirely adequate for analysing how transformative conservation captures and integrates deviations from organismic or ecosystemic norms. Their work nevertheless provides an interesting template for studying closely intertwined modes of nonhuman governance without reducing them to each other, or insisting on naming a single overarching logic superseding local or bounded biopolitical regimes.

Following Lorimer and Driessen's methodological proposal of multiplying the regimes in which animals or categories of animals can be enrolled, Timothy Hodgetts analyses the differing logics of pine marten and squirrel conservation in the UK, exploring "how conservationists enact multiple forms of biopolitics within seemingly singular situations."[56] He draws attention to specific instances of conservation, showing how the spatial practices of pine marten conservation operate mainly through techniques of security and constitute a milieu in which the collective and individual mobilities of martens are facilitated by the production of potential places (by offering den-boxes in potential suitable habitats). This he contrasts with the "affirmative biopolitics" engendered by squirrel conservation, which is carried out by tagging and carefully monitoring native red squirrels and culling invasive grey ones. This logic is prescriptive rather than speculative, aiming to purify the spaces in which red squirrels reside, and squirrel conservation therefore "operates according to the familiar anatamo-political (relating to bodies) and biopolitical (relating to populations) logics of nativeness, invasion, and biosecurity."[57] In addition to this meticulous characterisation of the different regimes at work in conservation projects, Hodgetts also notes that pine marten and red squirrel conservation sometimes merge. This is exemplified by recent ecological research supporting the hypothesis that pine marten presence could drive a decrease of grey squirrel populations, thus calling for "additional modes of spatial biopolitics" more focused on "targeting particular ecological processes as essential to achieving desirable

[55] Jamie Lorimer and Clemens Driessen, "Bovine Biopolitics and the Promise of Monsters in the Rewilding of Heck Cattle," *Geoforum* 48 (1 August 2013): 249–59,

[56] Timothy Hodgetts, "Wildlife Conservation, Multiple Biopolitics and Animal Subjectification: Three Mammals' Tales," *Geoforum* 79 (February 2017): 17–25,19.

[57] Hodgetts, "Wildlife Conservation," 21.

system properties" – fostering martens to cull grey squirrels.[58] This biopolitics is enmeshed with the growing reliance on a discourse of "ecosystem services" in wildlife conservation, and relies on a kind of animal self-government: sacrificial culling practices are replaced by newly enabled species interactions.

While this could be taken as an example of a positive valuation of animal agency, Hodgetts also points out that using population processes to keep invasives in check remakes species into political objects, even when (as in the case of pine martens and red squirrels) they are simultaneously enrolled as political subjects in other conservation projects. His analysis of the multiple biopolitics of wildlife conservation shows that objectification and subjectification are always partial and coexisting, resulting in an ontological multiplicity where differently motivated actors come together in conservation. This multiplicity becomes relevant in instances where "[t]he ways in which the tension between these various forms of biopolitical subjectification are worked out in specific practices is crucial to how animals are treated in contemporary forms of wildlife governance."[59] Hodgetts work connects to Lorimer and Driessen's in its implications for rewilding projects, as a paradigmatic example of conservation projects that render animals both as self-governing subjects and as "objects with ambiguous political status."

The work of these scholars reminds us that *population* never refers to a homogeneous, fixed, or single group of living beings. Any multispecies domain, and conservation in particular, is composed of variously constituted populations and regimes of management, in which the fostering of life and the sacrificial logic of culling are at play in different combinations and degrees. And crop wild relative conservation is an example of the emergence, in a conservationist space, of a new micro- or sub-regime of biopolitical management.

Here, the population to be managed is particular in that it is composed of two different categories of species that must be brought together and made to cooperate, species that may be related but have been managed under increasingly diverging regimes after the globalised logic of agribusiness severed the ties between cultivated plants and their wild and feral cousins proliferating at the margins of plots and fields. This merging of two close but differently structured biopolitical logics is the reason for the unstable status of crop wild relatives I have touched on above, as well as their institutional

[58] Hodgetts, "Wildlife Conservation," 23.
[59] Hodgetts, "Wildlife Conservation," 24.

vulnerability when it comes to closing conservation gaps: "[t]heir vulnerable position is compounded by the fact that crop wild relatives fall between the agricultural and conservation agendas: agriculture looks at tended lands, conservation does not focus on agricultural resources."[60]

In this new population composed of two categories of species, rendered differently as a result of diverging histories of management and institutional belonging, we see new forms of power relations and new subjects emerging. As in the management of grey squirrels through the fostering of pine marten populations, power here is exercised not merely *on* a species, a category of species, or an individual plant, but *through* the relations between species. And while Hodgetts' example is one where inclusion into different categories of species is predicated on binary oppositions between useful and destructive or native and invasive, the set of terms governing the distribution of crop wild relatives and domesticated plants into different categories is less agonistic and more ambiguous than in conservation projects pitting pine marten mobilities against grey squirrel invasiveness. In this instance, both crops and wild species are being fostered as agents able to connect and engage in the exchange of traits, and while hybrids are certainly being sacrificed during the pre-breeding process, they are so in a process whose outcome is collaboration rather than management through strategically fostered competition. Thus, crop wild relatives bring to the fore the possibility of conserving wild plants as multispecies, multi-agent, multimodal forms of heritage – as a compendium of the traces inherited from various interactions, biotic and abiotic, direct and lateral, sexual and environmental.

[60] "Crop Wild Relatives," Alliance of Bioversity International and CIAT, n.d., https://www.bioversityinternational.org/cwr/.

III. Interspecies Achievements

The previous section explored how the emergence of crop wild relatives as a category of species to be conserved in public-sector institutions devoted to wildlife conservation marks the emergence of a new, heterogeneous population composed of two categories of differently functioning and managed subjects. I have noted above that this emerging biopolitical focus on what happens between categories of species is critical for nuancing an analysis of crop wild relative conservation as merely the production of new commodities. Nevertheless, this relational dispositif enrols crop wild relatives into complex productions of freedom and creativity that are no less constraining or normative for being relational. Just like the cattle selected for rewilding projects mentioned by Hodgetts as well as Lorimer and Driessen, crop wild relatives are in the process of attaining an ambiguous status, between political subjects and exploitable objects. I will now turn my attention to the consequences of this shift, and explore the implications of conserving species as heritage, as processes, and as relationally constituted categories. As Lorimer and Driessen note about the challenges posed by rewilding to the other four modes of bovine biopolitics delineate in their article:

> These frictions centre on a series of questions, to which each mode of biopolitics provides a different answer. For example: Is the individual animal as important as the species? Is species an accurate and useful means for categorising difference? Does a list of current species provide the best way of measuring diversity and its dynamics? Is life a form or process? How do we live with evolution, emergence and risk?[61]

As a mode of biopolitics focused on species as relational processes, crop wild relative conservation provides its own set of answers to these questions. The constitution of this kind of population pulls together already established elements of the conservationist landscape and transforms them in the process. This comes with implications on the level of the institutions themselves (transforming what is conserved and how), of the plants concerned by this project (transforming their modes of relation), as well as that of the humans involved in conserving them (transforming their regimes of knowledge and attention).

[61] Lorimer and Driessen, "Bovine Biopolitics," 254.

1. Relational Resources and Interspecies Achievements

One crucial element in Hodgetts' work on the multiple biopolitical regimes of conservation is the emphasis he places on the normative effects of relational approaches. As he points out, the biopolitical logic of fostering processes rather than individual species for themselves is perfectly designed to support the economic discourse on ecosystem services (in which the composition of a given ecosystem matters less than its ability to still provide these services to humans, and in which these services provide the basis for valuing ecosystems). The confluence of pine marten and red squirrel conservation, focused as it is on what happens between dynamically mobile agents, is not merely a triumph of animal agency over reifying human practices. It is, rather, a technique of governance which "also serves to re-make the status of even the preferred species," shifting martens and squirrels back from the category of political "subjects" to that of means to achieve human goals. They are now "simultaneously enrolled as political subjects (in the sense of self-government outlined above), and as political objects (as mechanisms to achieve systemic goals for the benefit of human populations)."[62]

The situation of crop wild relatives is similarly ambiguous when they become enrolled in a logic first and foremost predicated on making use of their relationality. Just as the proliferation of animal subjects in political and scientific contexts marks the rise of their investment as knowable, perceiving, interpreting subjects of worlds and their management as such, providing opportunities for the expansion of subjectifying apparatuses of power, knowing and treating plants as relational does not necessarily problematise existing modes of ex situ governance.[63] It might even exacerbate this form of governance, allowing certain categories of species to be conserved with greater care on the basis of their ability to enter into specific forms of relations with others.

The ambiguous status of crop wild relatives is exemplified by the two possible approaches to pre-breeding. In their survey of crop wild relative use, Dempewolf et al. provide a concise summary of the two main avenues open to breeders:

[62] See Hodgetts, "Wildlife Conservation," 23–24.
[63] See Matthew Chrulew, "Animals as Biopolitical Subjects," in *Foucault and Animals* (Leiden, Boston: Brill, 2017), 22–238.

> "Choose first": wild materials that express a certain trait of interest are chosen on the basis of phenotypic, genotypic, or collection locality data and are used in targeted crossing, then the off-spring are evaluated; or (ii) "Cross first": a wider range of wild and domesticated materials are crossed and the resulting progeny are screened for traits of interest in the domesticated background.[64]

"Choose first" is an ideal approach for attempts at ordering and purifying the mechanisms by which these plants relate genetically. It relies on predictive characterisation, that is the screening of a plant's performance or genes in order to precisely identify the desirable traits that must be transferred into crop species. This approach mobilises a vast array of increasingly sophisticated genomic technologies, which break up inherited traces of interspecific interactions into alleles, markers, and regions. Bethke et al., in their survey of wild potato relative use, state their hope that the inefficiency of backcrossing processes will be remediated by high-throughput nucleotide sequencing. They forecast that "DNA markers will allow scientists to follow chromosomal regions in interspecific hybrids and select plants carrying desirable wild species genes," a technological development that might lift the barriers preventing widespread use of wild relatives in potato breeding.[65] This ongoing dismemberment of crop wild relatives into segmented genomes also links organically into more interventionist genomic technologies. Dempewolf et al., for instance, note that "the advent of genome editing is predicted to revolutionize plant breeding […]. Although these methods are still in their infancy, their increased precision will likely result in substantial efficiency gains in crop improvement processes."[66]

It would thus seem that exerting influence through the relations that can or cannot form between species immediately leads back to the reductionist moves of genetic fetishism. Montenegro de Wit certainly argues this point when she notes that the pre-breeding preceding any possible future use of "enhanced" germplasm by farmers ends with a process of "[w]eeding out [the] unwanted wildness" of crop relatives.[67] This final stage consists in repeated and careful backcrossings that eliminate remnants of linkage drag (the unwanted effects of genes linked to the ones that breeders are trying to introgress into the crop they are working with), ideally arriving at an almost identical version of the initial crop species enhanced only by a few select wild genes.

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64 Dempewolf et al., "Past and Future Use," 1072.
65 Paul C. Bethke, Dennis A. Halterman, and Shelley Jansky, "Are We Getting Better at Using Wild Potato Species in Light of New Tools?," *Crop Science* 57, no. 3 (2017): 1241–1258, 1249.
66 Dempewolf et al., "Past and Future Use," 1076.
67 Montenegro de Wit, "Stealing into the Wild," 23.

It is however important to take a step back and examine what the concrete process of pre-breeding entails. This begins with the fact that while much work is currently being done to further the genetic analysis of crop wild relative accessions, it seems that the "choose first" approach is not as unproblematically accessible as many scientists would wish. Crop wild relative breeding is far from being done with the accidents of the field, as Burgarella et al. point out:

> In the end, the validation of adaptive introgression detected via molecular data would need the association of classical experiments to measure the strength of selection in the field and to assess the biological function of the introgressed alleles.[68]

"Cross first," in fact, still appears to be the main avenue for pre-breeders working with crop wild relatives, both because genomic technology is not advanced enough to allow for easy screening and selection of traits, and because this strategy, "though much less focused initially, has the potential to reveal unexpected sources of diversity that only become apparent when introgressed in a domesticated background."[69] This does not mean that the increased agency attributed to plants when they are allowed to cross freely translates into greater independence from human goals: here it is the relations between species that become the resource to be exploited.

But this mobilisation is still, as of now, slowed down by a considerable amount of recalcitrance on the part of the plants themselves. The contingency of these "classical experiments," and the intense physical and mental labour required to bring about even just a few hybrid lines, is recounted with a healthy dose of humour in a blog post of the Crop Wild Relatives Project website. The post quotes two researchers working on lentil pre-breeding, Albert Vandenberg and Richard Fratini. The former provides an accurate if irreverent summary of what pre-breeding on the ground entails:

> It isn't always easy. Vandenberg explains that there are two kinds of breeding in lentil. "In the primary genepool we call it 'Singing,' Systematic Introduction of New Germplasm. But when it comes to the secondary and tertiary gene pools, we call it 'Screaming,' which is Systematic Creation of Exotic and really

[68] Concetta Burgarella et al., "Adaptive Introgression: An Untapped Evolutionary Mechanism for Crop Adaptation,' *Frontiers in Plant Science* 10 (1 February 2019): 4, 12.
[69] Dempewolf et al., "Past and Future Use," 1072.

Awful Material." He laughs. "Or: Slow Critical Research that Eats All your Money."[70]

The same issue is flagged by Fratini, who describes the harrowing process of producing a total of eleven hybrid lentil seedlings. These eleven plants are the result of Fratini's work on almost a thousand crosses, all of them pollinated by hand in the greenhouse during an intense three-week stretch. Only seventy-nine of these crosses produced properly fertilised ovules, and Fratini was only able to "rescue" eleven embryos strong enough to develop shoots and roots. But that is not the end of it: "once big enough, he will need to confirm if they are real crosses and make fertile plants that set seeds. If no seeds are set, they are of no use and it is back to square one." And whichever plants prove fertile will then have to be tested in the field to see if they have inherited any useful traits at all. These anecdotal descriptions of day-to-day attempts at choreographing new interspecies achievements in a laboratory setting show that nothing about the experimental mobilisation of crop wild relatives is as straightforward as the genomic literature on the subject might suggest.[71] Even when they are ultimately enrolled in the production of commodities or of fungible, exploitable natural resources, these achievements and the labour necessary to bring them about must be explored without immediately subordinating them to such an overarching project. Doing so would obscure the difficult and complex production of expertise created through these negotiations.

2. Practices and Techniques

The achievements arrived at by plants in experimental plots are constructed by and for the human researchers who have stakes in the success of these operations. As we have seen, both conservationist and agro-ecological spaces are impure types of laboratories, in which the boundary between experiment and external influences – and between the experimenters and their subject matter – is even more difficult to draw, and where such forms of purification are not necessarily crucial to conducting the work that needs to be done. Collecting and breeding does not transform only the bodies and the vitalities of wild

[70] Elsa Matthus, "Lentil Serendipity – and Hard Work," The Crop Wild Relatives Project (blog), 4 May 2017, https://www.cwrdiversity.org/lentil-serendipity-and-hard-work/.

[71] On the notion of experimental sciences involving nonhumans (and more specifically animals) as interspecies achievements, see for instance Despret, *What Would Animals Say* and Dominique Lestel, *L'animal Singulier* (Paris: Seuil, 2004).

and domesticated plants; the consequences of such a project ripple out into the practices and epistemologies of the scientists and breeders involved.

Dominique Lestel, as part of his project to construct a robust philosophical ethology, has emphasised the need to take a range of "marginal epistemologies" seriously if we are to conduct a pluralistic and non-mechanical form of inquiry.[72] Unlike academic ethology and its claims to universality, such attention would recognise the need "to leave some room for marginal explications coming from other cultures and/or from professionals working with animals,"[73] and accept that the expertise accumulated by professionals working in close contact with other species – such as breeders, hunters, trainers, zookeepers, wildlife photographers and so forth – is of crucial significance for a "dialectical ethno-ethology,"[74] since they establish a space of shared meaning, shared histories and of negotiation processes in which the animal is never merely a mechanical means to an end but a subject and a partner, even when power relations are asymmetrical.[75]

While Lestel's philosophical ethology is focused more specifically on animal species, it is possible to give it a more generous extension that would include practitioners working in other kingdoms. Viewed through this lens, crop wild relative pre-breeding projects appear as unexpected, potential sites of such a "marginal" epistemological production. Here the relations created and the knowledge amassed do not concern a singular animal; the pool of subjects is wider and perhaps more undifferentiated in experimental pre-breeding plots than it is in the practices singled out by Lestel. But if we take *species* to be an appropriate level of ethological involvement with plants, and changing models of interspecies relations as a form of interpretation of how these species construct worlds and cohabitations, the difficult achievements of pre-breeding might appear at least as a proto-communal space of mutual influence. As Friese shows in her work on the cloning of endangered species in zoos, certain captive breeding projects function as reproduction of "skills and knowledge practices": "[c]loning does not simply make individual animals; it also makes technically skilled scientists, knowledge practices, and populations of animals."[76]

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[72] Dominique Lestel, "What Capabilities for the Animal?," *Biosemiotics* 4, no. 1 (1 April 2011): 83–102, 83.
[73] Lestel, "What Capabilities," 89.
[74] Matthew Chrulew, "The Philosophical Ethology of Dominique Lestel," *Angelaki* 19, no. 3 (3 July 2014): 17–44, 30.
[75] See Dominique Lestel, *L'animal Singulier* (Paris: Seuil, 2004).
[76] Friese, "Cloning in the Zoo," 274.

At the beginning of this chapter, I mentioned the plight of commercially grown bananas, mostly made up of orphaned and sterile species reproduced vegetatively rather than sexually in vulnerable plantations. Another species of the *Musaceae* family, the Ensete ventriculosum – also known as the Ethiopian or false banana, and grown for its root and leaves – suffers from the same structural issues. The attention trained on its wild relatives as a potential source of resistant traits has already spawned research into ignored or lost knowledge about domesticated crops, turning enset conservation into a site of marginal epistemological production similar to what Lestel and Friese describe. Notably, a forthcoming study involving researchers from the Addis Ababa University, the Millennium Seed Bank and the Katholieke Universiteit Leuven, recapitulates germination tests conducted with twenty enset seed accessions – thirteen domesticated species sourced from Ethiopian farmer's fields with their permission, and seven wild collections "made in river valleys at least 1 km from settlements cultivating enset, to mitigate the risk of feral or recently introgressed individuals."[77] Unlike the *Musa* species that make up most of the bananas and plantains grown and consumed worldwide, *Ensete ventricosum* is only cultivated in Ethiopia; but its weaknesses are similar to *Musa* species in that "sophisticated agronomic practices were developed to enable exclusively vegetative propagation" during its domestication. Reduction of sexual fertility is one of the identified characteristics of domestication syndrome in clonally propagated crops, and a lack of knowledge about enset pollinators, their assumed disappearance from cultivated lands, the practice of harvesting before flowering, and lack of incorporation of wild or sexually reproduced seedlings into cultivated populations lead the authors to conclude that "little to no indigenous knowledge pertains to enset seed germination" (they do mention, however, that there is a long history of indigenous knowledge accumulation when it comes to the vegetative propagation of these plants).[78] Studying wild seed germination allows for a comparative study of domesticated and wild characteristics, which the authors expect to be similar if viable sexual reproductive potential has been retained during domestication – a conclusion the article ultimately arrives at. The possibility of sexual reproduction is an achievement that botanists working with parthenocarpic crops are desperately pursuing; as Tamrat et al. note, the (regained) ability to reproduce sexually will be of crucial importance for conserving these crops, as clonal reproduction

[77] Tamrat et al., "Germination ecology of Ensete ventricosum," "Materials and Methods."
[78] Tamrat et al., "Germination ecology of Ensete ventricosum," "Introduction."

makes their maintenance ex situ difficult and "could significantly hinder future perennial crop breeding programmes and integration of diversity from crop wild relatives."[79] And in order to arrive at the knowledge that would enable both the conservation of *Ensete* seeds and their enrolment into experimental relationships with their relatives, scientists have to construct hypotheses concerning which sets of interactions and relations have shaped enset evolution and which ones have disappeared or been suppressed and would need to be reactivated in order to create the possibility for dormant traits to express themselves. This is only one example of how crop wild relative conservation and use prompts the reconstitution of lost knowledge, sometimes by making the human partners of these experimental achievements step into new roles (such as that of an absent pollinator) in order to facilitate intra- and interspecies transactions.

Creating, rediscovering, reordering or inducing forms of knowledge, as the researchers cited above are doing, does not only affect the subjectification and treatment of crop wild relatives. As Lestel and Despret would argue, collaborating with nonhuman others in experimental settings never leaves human participants unchanged; while positivist ethology might attempt radical forms of experimental purification, understanding and generating truly interesting nonhuman capabilities demands that the experimenter allow themselves to become affected by and interested in their collaborators.[80] The overarching project of crop wild relative utilisation is rightly associated with the possibility of an increased neoliberal hold on commodified natural resources by the private sector and a dispossession of small farmers, local communities and indigenous people, not leaving much room for alternative biopolitics (not to speak of the possibility for other forms of resistance). But the concrete, embodied, emplaced processes by which this project is realised are sites where less obviously managerial and exploitative figures emerge and proliferate.

One aspect in particular of this transformation and problematisation of scientific and cultivation practices ties back to a point explored in my analysis of assisted migration in the previous chapter. Just as the emergence of speculative assisted migration projects illuminated the gaps and insufficiencies of currently available ex situ collections, studying and addressing the structural weaknesses of conservation practices is a goal explicitly

[79] Tamrat et al., "Germination ecology of Ensete ventricosum," "Introduction."
[80] See for instance Vinciane Despret, *What Would Animals Say If We Asked the Right Questions?*, trans. Brett Buchanan (Minneapolis: University of Minnesota Press, 2016) and Dominique Lestel, *Les Origines Animales de La Culture* (Paris: Flammarion, 2001).

inscribed into the development of the Crop Wild Relatives Project. We have already seen how time-consuming and uncertain the pre-breeding process can be, especially when it relies on empirical and traditional breeding techniques rather than genetic manipulation technologies still in their infancy. The need for integrating a variety of breeding techniques means that the collection and study of crop wild relatives hovers between scientific and empirical breeding, imperial science and attention to indigenous and folk modes of knowledge and cultivation practices. This is also true of all the steps that have to take place before these plants can be bred, which include the assessment of existing accessions and of their gaps, and the development of more robust collections. I argue that in negotiating this stage of crop wild relative conservation, conservationists and pre-breeders extend the range of the roles they can play – a range which edges, as it did in assisted migration projects, into what could be called hunting territory.

3. Hunting Practices

Here, as in the preceding chapter, Frédéric Keck's approach to techniques of pandemic preparedness provides a useful guide. More precisely, his distinction between storage (of viral samples) and stockpiling (of flu vaccines), and the associated pastoral and cynegetic regimes, can be applied to the collection and use of crop wild relatives. Both, according to Keck, are "modes of production of biovalue"; both are anticipatory techniques. Stockpiling is the practice of transforming a natural resource into a social one by imagining a shortage on a social level – a bottleneck in the distribution of medical supplies – and "reorganiz[ing] society in the imaginary enactment of a catastrophe."[81] Storage, by contrast, responds to a scarcity imagined at the level of nature, and it preserves "all kinds of tools and materials, inasmuch as they can be used for different purposes."[82] Stockpiling crop wild relative germplasm in the hopes of one day being able to use these hybrid lines in conventional agriculture without too much friction would demand the standardisation of collected material. But before this can even become a possibility, the constitution of viable stock must follow the storage logic of collection, which fills in gaps by tracking down individualised accessions and confronting the

[81] Frédéric Keck, "Stockpiling as a Technique of Preparedness: Conserving the Past for an Unpredictable Future," in *Cryopolitics: Frozen Life in a Melting World*, ed. Joanna Radin and Emma Kowal (Cambridge, Massachusetts: MIT Press, 2017), 133.
[82] Keck, "Stockpiling as a Technique of Preparedness," 135–136.

uncertainties and contingencies of existing collections. As Keck says of viral strain storage:

> The collection and preservation techniques of microbiologists may be closer to those of highly skilled hunters, who follow the lines of animal movements and trace their relations of kinship, than to those of pharmaceutical companies.[83]

This definition also applies to the practices of the scientists and breeders involved in the gap-filling stage of the Crop Wild Relatives Project. In an interview titled, appropriately, "Hunting for Drought Tolerance in Papua New Guinea," Sebastien Carpentier – a bioscience engineer based at KU Leuven and conducting pre-breeding in partnership with the Crop Wild Relatives Project – recounts the expedition he led to find more drought-tolerant *Musa* species in Papua New Guinea. When prompted, he notes that collecting and pre-breeding are difficult to separate when it comes to crop wild relatives; for Carpentier's team, the necessity to collect more accessions arose from difficulties encountered in regerminating the accessions sent to them by the Millennium Seed Bank. The reason why he and his team visited a range of very different environments to collect seed is that they were hunting not so much for species but for the variability range of traits within those species:

> See, we want to identify – to really pinpoint – the individuals that have adapted to these harsher conditions. *Those* have the traits we are after for our breeding efforts, to improve drought tolerance of the bananas we eat on a daily basis.[84]

In doing so, Carpentier and his colleagues – just like the researchers trying to piece together clues about the absence or dormancy of sexual reproduction in ensets – have to undergo a process of attuning to an environment. Even for a very short time, such as the duration of a collecting expedition, and by enlisting the help of people only identified as "local guides" in one of the pictures accompanying the interview, they must learn to track and find not only a species but the particular individuals adapted to particular niches. "And as pre-breeders," he continues, "we know the kind of diversity we need. We can recognize it when we see it in the field."

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[83] Keck, "Stockpiling as a Technique of Preparedness," 136.
[84] Sebastien Carpentier, "Hunting for Drought Tolerance".

In a similar vein, Tamrat et al. mention a form of hypothesising that skews remarkably close to the exchange of perspectives that Keck identifies as characteristic of hunting practices.[85] While the germination tests they conduct on collected enset seeds rely on a set of laboratory techniques reducing those seeds to easily measurable morphological data and allowing for a rationalised germination trial protocol, their observations in the field involve tracking signs of potential interaction and significant details providing clues about the plants' sexual behaviour. The article cites observations made by one of the authors, James Borrell, who "found no evidence that certain landraces have lost the propensity to flower, which appears consistent with farmer perceptions," and notes that the ostentatious planting of a single ornamental enset, left to flower in a visible spot of wealthy farmers' compounds instead of being harvested, might enable continued sexual recombination.[86] This study also leads its authors to form various hypotheses, supported by an embodied knowledge of the field, about the history of interactions that have shaped wild and domesticated ensets. They speculate about the absent species that might have once pollinated them mentioned above and entertain the possibility that a small number of wild seedlings are integrated into farms solely for the purpose of harvesting leaves, a process which demands a certain degree of identification with these plants and the ability to understand their relationships with other species from their point of view. In this, their methods also come close to what Norman Ellstrand has called the detective work of scientists trying to piece together the possible histories of wild-crop introgressions. In playful vignettes scattered between the technical chapters on genetics of his book *Dangerous Liaisons?*, Ellstrand presents what he calls the "Case of the Bolting Beets," in which scientists tried to solve the mysterious appearance of weed beets in European sugar beet fields around the 1970s. In this process, the analysis of genetic markers allowed the reconstitution of the historical and geographical pattern of gene flow from wild sea beets to cultivated sugar beets and led scientists to hypothesise about the individual mutations and biographical accidents of the original hybrid parent plants.[87]

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[85] See Keck, *Avian Reservoirs*, 109. On perspectivism and the exchange of perspectives more generally, see for instance Eduardo Viveiros de Castro, "Cosmological Deixis and Amerindian Perspectivism," *The Journal of the Royal Anthropological Institute* 4, no. 3 (September 1998): 469 and Eduardo Kohn, *How Forests Think: Toward an Anthropology Beyond the Human* (Berkeley: University of California Press, 2013

[86] Tamrat et al., "Germination Ecology of *Ensete ventricosum*," "Discussion."

[87] See Norman C. Ellstrand, *Dangerous Liaisons?: When Cultivated Plants Mate with Their Wild Relatives* (Baltimore: John Hopkins University Press, 2005), 74.

While the pre-breeding of new hybrids and the choreographing of new interspecies relations in experimental settings participates in biopolitical modes that enforce certain ideal biological and economic norms and rely on sacrificial procedures in the name of enhanced performance, it also engages in a mode of production that makes hunters out of scientists. Theirs is a form of institutional ferality replaying or redoubling that of their ambiguous subjects. It is not only wild species that are resituated or looked for in the weedy margins of human activity and agricultural plots, but also humans who have to venture into these margins and adopt modes of attention and collection which, while still serving hegemonic agricultural goals, are more adapted to the spaces in which they have to operate. Rodney Harrison, in his work on the ontological politics of heritage, indicates that one of the themes orienting his proposed research project on "new heritages" is the management of "nature/culture borderlands," a useful term for characterising the sites of crop wild relative conservation. While he is speaking specifically of "synergies between landscape rewilding initiatives and the management of ruination in built heritage" in this article, his argument that heritage should be understood as a set of diplomatic properties that arise from interactions between human and nonhuman actors is useful for framing wild relatives as examples of such heritages. The borderlands Harrison mentions are precisely where these forms of dynamic, ambiguous and exploitable heritage are now to be managed.[88]

What emerges here is a first indication that the cosmology enacted by crop wild relative conservation projects is one in which *domestication* operates as an ordering device and as a contested category in the process of being questioned and renegotiated, sometimes through the enactment of its seeming opposite in the form of hunting-gathering practices. This will be the focus of the closing section of this chapter, in which I will turn to the question of how domestication is being replayed and complicated in and through crop wild relatives, and with what effects.

[88] Rodney Harrison, "Beyond 'Natural' and 'Cultural' Heritage: Toward an Ontological Politics of Heritage in the Age of Anthropocene," *Heritage & Society* 8, no. 1 (May 2015): 24–42, 37.

IV. Renegotiating Domestication

1. Categories and Processes

The set of categorial slippages and shifts, multiple biopolitical belongings, and ambiguous scientific practices I have explored in the preceding sections of this chapter are indicative of the marginal nature of the Crop Wild Relatives Project, and of projects breeding crop wild relatives with domesticated species in general. Categories are uncertain, and statuses uneasy, because scientists and plants both exist in the liminal space created by institutions such as the Millennium Seed Bank. This is a term used by Kay Lewis-Jones in her ethnographic inquiries into this seed bank, in which she uses the concept of liminality to describe the material practices of seed banking. Lewis-Jones examines how the Millennium Seed Bank ensures seed survival by disentangling plants from space and relations, a process that reinforces and remakes those seeds' "ability to simultaneously embody continuity and novelty, as well as to be temporally and spatially dispersed."[89] While this participates in what she calls the "topological tactics of extraction and mobility" and serves a neoliberal logic of circulation, she also proposes to read the work of the Millennium Seed Bank as the creation of a liminal or heterotopic space, in which the suspension of the seeds' entanglements might also allow a slowed-down, thoughtful reconfiguration of ecological communities. The experimental projects enabled by the availability of conserved seeds, seen in the context of liminality, are opportunities "to think slowly with each species – potentially for centuries."[90] While Lewis-Jones does not explicitly name the Crop Wild Relatives Project, this initiative – along with the myriad of other similar conservation and pre-breeding efforts that have taken place in other institutions – is one of the various loci making up this distributed and interlinked heterotopia. This technoscientifically-mediated liminality, as Lewis-Jones notes, offers a (fraught) opportunity to pause and re-imagine biosocial articulations in "a space in which the imaginative constraints of existing relations are transcended."[91]

[89] Lewis-Jones, 'Holding the Wild in the Seed', 6.
[90] Lewis-Jones, 'Holding the Wild in the Seed', 7.
[91] Lewis-Jones, 'Holding the Wild in the Seed', 6.

In this peculiarly suspended experimental space, nature – if that term can still be used – is made visible as an intensely metamorphic zone, a term which I borrow from Latour via Despret. Traits – the main focus of the transactions and efforts taking place in assisted gene flow experiments – are not only a matter of genetic identification; as Despret points out, they are also traces of "active and creative writing," traces "actively written by other living or nonliving beings in the course of the long history of evolution, in the body or in the being."[92] The conservation of crop wild relatives deals with "morphisms," in the "*surprising kinship* of ways of affecting":

> The "morphisms" of which Latour speaks are the transformations, bifurcations, exchanges "of forms of action through the transactions between agencies of multiple origins and forms": all the beings involved take their very form – the forms of their ways of being and of their modes of action – as so many effects of these connections with other ways of being and of acting.[93]

Conserving crop wild relatives – hunting for them in the field and luring them into interspecies achievements in experimental plots – falls into the category of what Stengers also calls "practices that [...] explore a metamorphic (rather than representational) relation to the world." [94] Significantly, she cites agriculture as a "craft requiring or depending upon a capacity to lure us into relevant metamorphic attention" – along with "politics, healing, education, arts, philosophy, sciences" and so forth. Purely pastoral categories of analysis are insufficient to fully capture what is being negotiated in crop wild relative conservation and breeding; to analyse what happens in liminal spaces, one must start talking at least partially in cosmological terms. Relying only on the grammar of agricultural relations would mean treating the agents circulating in conservation and processes – both wild and domesticated – as already stabilised and well-defined when this process starts, rather than emerging from it. The processes I have outlined in this chapter, by which different categories of species are brought together into precariously choreographed achievements, thereby transforming the practice and knowledge necessary for these achievements, are neither singular, linear, or certain. As we have seen in the previous section, the project of pre-breeding ensets and bananas reveals that we

[92] Despret, "Traits," 188.
[93] Despret, "Traits," 186.
[94] Stengers, "Reclaiming Animism."

lack much of the necessary knowledge to lure their wild cousins into the relationships that would ensure the success of these projects.

2. Domestication, Replayed

As I have already mentioned, this process, or rather set of open processes, that scientists involved in crop wild relative conservation are engaged in, have to do with the history of domestication. In assisted migration, we have seen life managed through the enrolment and redeployment of migrational movements antedating recorded human history and, in some cases, the Holocene itself. Breeding crops with wild relatives similarly functions by applying a process, modelled on previously existing relations and flows, to endangered forms of life in order to manage their vitality. In this case, the process in question can be more accurately and securely identified in the chronology of human history than contested palaeoecological data, provided one subscribes to a linear historical understanding of the Neolithic Revolution.

Before returning to the question of domestication practices proper, it should be noted that it might seem paradoxical to insist that the transformation of scientists into hunters, which I have expanded on above, is precisely that which indicates that *domestication* is at stake here. But recent anthropological scholarship has done much to undo rigid distinctions between hunting-gathering and agricultural and pastoral regimes, training our attention on the ambiguous gradations between these two poles.[95] Some anthropologists, such as Rane Willerslev, Piers Vitebsky and Anatoly Alekseyev, even argue that the domestication of reindeer in the Siberian Northeast – and the sacrificial practices it allows and requires – can be understood as a solution to the tensions inherent to reindeer hunting. In a comparative study of ritual re-enactments, they show that there is a "structural identity between hunting and sacrifice," and ask whether, "rather than marking a radical shift in people's relationship to animals, this transformation represents a continuation and refinement of the hunters' attitude towards prey."[96] Accounts of hunts in which the animal "gives itself up" to be killed – in the context of an intimate and

[95] For a discussion of the debates arising around the issue of distinctions between hunter-gatherer and agriculturalist societies, see Keck, *Avian Reservoirs*, 167–69.
[96] Rane Willerslev, Piers Vitebsky, and Anatoly Alekseyev, "Sacrifice as the Ideal Hunt: A Cosmological Explanation for the Origin of Reindeer Domestication: Sacrifice as the Ideal Hunt," *Journal of the Royal Anthropological Institute* 21, no. 1 (March 2015): 1–23, 4.

symmetrical relationship with the hunter – must be nuanced and resituated within a wider set of discourses and attitudes, which encompasses both the "official discourse" of informants and everyday practices deviating from it.

On the basis of a reworked Ingoldian distinction between a regime of trust between hunters and prey, with the latter actively colluding in their capture, and a pastoralist relation of domination over livestock, they hypothesise that "hunters' discourses about hunting, which are then passed on by anthropologists, do not so much denote the hunt as it is but rather represent an *ideal*, which stands in conscious contrast to the course of things during actual hunting."[97] The double bind thus imposed on hunters is apparent in various Siberian practices designed to conceal the violent aspects of hunting, and one of the methods for overcoming this double bind might have been the switch from hunting to ritual blood sacrifices in certain Siberian groups, which involve the creation of a ritual perfection impossible to obtain during a hunt and necessitate the creation of a new category of tamed animals. By taming specific animals in order to prepare them for blood rituals and stage their acquiescence to said rituals, hunters "open up a new format (and perhaps historical stage) in relations between animals and humans."[98] Willerslev, Vitebsky, and Alekseyev thus complement economic and ecological explanations of the switch from hunting to taming with a cosmological one, proposing that domestication might also be thought of as a by-product of the need to close a gap between words and deeds.

While their case studies are not directly related to the practice of crop wild relative conservation and breeding, the idea that taming and hunting practices are causally imbricated is an intriguing proposal, and one which complicates any simple distinction between the violent pastoral regime of agriculture and the local, attuned, mutualistic practices of plant hunting. Arguing that crop wild relative conservation makes use of techniques of capture and power lying outside of the pastoralist remit does not imply that the emergence of this project drags conservation back into a supposedly pre-domesticated past, or that it marks a welcome diversification of conservationist practices into richer and more local indigenous practices identified with premodern history – an argument that would be guilty of what the anthropologist Johannes Fabian has termed a

[97] Willerslev, Vitebsky, and Alekseyev, "Sacrifice as the Ideal Hunt," 8.
[98] Willerslev, Vitebsky, and Alekseyev, "Sacrifice as the Ideal Hunt," 16.

"denial of coevalness."[99] As Keck has shown, the coexistence of pastoral and cynegetic techniques in pandemic preparedness does not necessarily undo the violent interventions into nonhuman life performed by either.[100] Their coexistence in conservation practices signifies not a *return* to pre-domesticated conditions but a *reprisal* of one of the processes by which wildness and tameness are negotiated, and species brought into a space in which domestication – or another transformative process at the human-animal interface[101] – might or might not take place. It is a contemporaneous staging of a history of domestication that is ongoing rather than bounded and stabilised. In dealing with their heterogeneous population of plants participating in very different biopolitical regimes, scientists are not called upon to be only farmers, the managers of a set of domesticated relations already in place. They are transformed, rather, into actors hovering at the very margins of domestication, hunting-gathering scientists whose activities operate outside of the bounded sphere of domestication while also functioning as the process by which new species are to be brought into this very sphere.

3. Borderlands

Paying attention to such a reprisal of a process of pre- and proto-domestication leads us into the very particular space that is managed and explored in the search for crop wild relatives. That space is the margin or border in which many of the metamorphic interactions that make domestication possible take place. Conventional narratives and concepts of domestication have increasingly come into question in recent scholarship, a process that has opened up the possibility of emphasising nonhuman agency in processes of taming and domestication.[102] Thus Van Dooren, in a response to conventional accounts of domestication, notes that the idea of separate realms is in itself problematic, and that

[99] See Johannes Fabian, *Time and The Other. How Anthropology Makes Its Object* (New York: Columbia University Press, 1983).

[100] See Keck, *Avian Reservoirs*.

[101] See Dominique Lestel, *L'Animalité. Essai Sur Le Statut de l'humain* (Paris: Hatier, 1996).

[102] See for instance Lestel, *L'Animalité*; Dominique Lestel, 'How Chimpanzees Have Domesticated Humans: Towards an Anthropology of Human-Animal Communication', *Anthropology Today* 14, no. 3 (1998): 12–15; Rebecca Cassidy and Molly H. Mullin, eds., *Where the Wild Things Are Now: Domestication Reconsidered* (Oxford, New York: Berg, 2007); Heather Anne Swanson, Marianne E. Lien, and Gro Ween, eds., *Domestication Gone Wild : Politics and Practices of Multispecies Relations* (Durham: Duke University Press, 2018); Sue Donaldson and Will Kymlicka, "Between Wildness and Domestication: Rethinking Categories and Boundaries in Response to Animal Agency," in *Animal Ethics in the Age of Humans: Blurring Boundaries of Human-Animal Relationships*, ed. Joseph Keulartz and Bernice Bovenkerk (Berlin: Springer, 2016).

"many plants are involved in ongoing interactions across the wild/domesticated border."[103] Doing so, he emphasises ongoing human dependence on non-domesticated biodiversity, the insertion of human activities into much older histories of co-evolution between plants and their pollinators and dispersers, and the agency of plants in the process of domestication – going as far as to suggest that the "human *invention* of agriculture might be rethought in a way that also acknowledges the *teaching* of agriculture to human by plants," in particular those plants growing opportunistically around human communities.[104]

This border, the margin in which various interspecies relations prepare the ground for human interventions and, ultimately, domestication, is where the search for crop wild relatives ventures. I have already mentioned the marginal nature of crop wild relatives, who by and large tend to fall between institutional cracks and are seen as weedy species by conservationists and farmers both. While this is a fact often bemoaned in the gap analyses of extant seed collections I cited earlier, I would argue that their marginal status is not an accident, but rather indicates that they are located in precisely those spaces into which this project is meant to intervene. And these material and metaphorical borders, into which conservation biology is in the process of venturing once again, are spaces in which domestication is not a completed process, or has not even started; where, before even dreaming of becoming farmers, biologists must re-enact the very first steps of taming and reciprocal capture. As Swanson, Lien and Ween note in their introduction to the volume *Domestication Gone Wild*, marginality is a constitutive element of practices and discourses of domestication:

> Marginality (like periphery) is constantly made, enacted by narratives as well as practices. Hence, domestication (like modernity) can be seen as a project that constantly produces its own outsides as well as "outsiders within," which, in turn, can be mobilized to justify expanding and civilizing efforts heralded through the idiom of domestication. Through ethnographic attention to domestication assemblages that are marginalized, we can show how multispecies relations become implicated in contexts of colonial expansion, in the making of resource frontiers, and in other efforts associated with progress.[105]

[103] Thom Van Dooren, "Wild Seed, Domestic Seed: Companion Species and the Emergence of Agriculture," *PAN: Philosophy Activism Nature* 9 (2012): 22–28, 24.
[104] Van Dooren, "Wild Seed, Domesticated Seed," 25.
[105] Swanson, Lien, and Ween, *Domestication Gone Wild*, 3.

Reconnecting with older practices of acclimatisation and introduction of plants by botanic gardens, wildlife conservation is pulled into the continued expansion of human agency, techniques and apparatuses, guided by progress narratives, into the last weedy margins of agricultural systems. Thus the enrolment of wild relatives is, sometimes, explicitly referred to as a form of "de novo domestication." Zsögön et al., for instance, equate the devising of a "CRISPR–Cas9 genome engineering strategy to combine agronomically desirable traits with useful traits present in wild lines" with such a de novo domestication of the wild tomato relative *Solanum pimpinellifoliu*m.[106] Genome editing is synecdochally substituted for the entirety of the multispecies interactions needed to bring about a relation of domesticity, and domestication itself is identified with *domestication traits*, which amount to merely six key loci in the tomato genome – previously undetected "hidden domestication genes" made exploitable by advances in genetic analysis.[107] This is an extreme example of this domesticatory colonisation of wild margins, one that is sometimes referred to as *superdomestication* – a set of "processes that lead to a domesticate with dramatically increased yield that could not be selected in natural environments from naturally occurring variation without recourse to new technologies."[108] Often placed into a linear genealogy spanning traditional propagation, scientific breeding through crossing programs and field trials, and more recent developments in marker-assisted breeding, this superdomestication culminates in the dream of being able to produce a "definition of a cultivar with a suite of ideal characters ranging from biotic and abiotic stress resistance, through yield, to post-harvest and nutritional quality."[109]

While assisted gene flow from wild relatives to domesticated species certainly constitutes a form of colonisation of the weedy margins of agriculture, and thus an apparatus for the making of what Swanson, Lien and Ween call "resource frontiers" – the new types of seed enclosures also analysed by Montenegro de Wit – we must be careful to nuance this analysis by noting that this very emphasis on marginal spaces problematises their absorption into an ever-expanding sphere of domesticates. Just as assisted migration does not enable the immediate expansion of large-scale

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[106] Agustin Zsögön et al., "De Novo Domestication of Wild Tomato Using Genome Editing," *Nature Biotechnology* 36, no. 12 (December 2018): 1211–16, 1211.
[107] Duncan A. Vaughan, E Balázs, and J.S. Heslop-Harrison, "From Crop Domestication to Super-Domestication," *Annals of Botany* 100, no. 5 (November 2007): 893–901, 897.
[108] Vaughan, Balázs, and Heslop-Harrison, "From Crop Domestication to Super-Domestication," 899.
[109] Heslop-Harrison, "Genomics, Banana Breeding and Superdomestication," 55.

geoengineering projects, crop wild relative conservation does not open up the possibility of moving smoothly from collecting a wild relative to developing a new superdomesticate containing some of its traits. And even if that were the case, the aim of pre-breeding projects is not to domesticate the wild relatives themselves, but rather to keep them available for domestication projects in a way that does not fully reduce them to commodities.

These scientists are in fact engaging in a positional understanding of wildness and domesticity, in a way akin to that of people described by various contemporary anthropologists. Another seemingly remote example drawn from anthropological accounts is that of pigs in Ifugao, studied by Jon Henrik Ziegler Remme. Recounting the chase after a pig to be presented as a bride gift to prospective parents-in-law, Remme shows that, in this part of the Philippines, various forms of domestication coexist and that "these domestication practices occur within a relational field that is more extensive than is often assumed."[110] In Ifugao, pigs exist in a cosmological frame in which they can be enacted as domesticated or wild depending on the context. "Domesticated" house pigs are raised and fed for sacrificial purposes; healing rituals in particular imply the enactment of hunting practices in which those pigs are transformed into wild ones again, so that they may be returned to the spirits. Conversely, "wild" pigs roaming the forest are occasionally hunted; but for the hunt to be successful, they must be acknowledged as the domesticated property of the *pinādeng* spirits populating those forests, and without whose voluntary relinquishing of said property the hunt could not be successful. Remme proposes an interesting challenge to the idea that domestication is necessarily an epochal, unilinear and irreversible change in human-animal relations, by showing that when viewed cosmologically wildness and domesticity are a matter of ownership, perspective, and position. And a wide range of other scholarship has revealed the instability of the notion of domestication and opened up the possibility of renewed understandings of such marginal natural-cultural practices.[111]

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[110] Jon Henrik Ziegler Remme, 'Pigs and Spirits in Ifugao: A Cosmological Decentering of Domestication', in *Domestication Gone Wild: Politics and Practices of Multispecies Relations*, ed. Heather Anne Swanson, Marianne E. Lien, and Gro Ween (Durham: Duke University Press, 2018), 51.

[111] See for instance Dominique Lestel, *L'animal Singulier* (Paris: Seuil, 2004) and Lestel, *L'animalité*; Vinciane Despret, *The Dance of the Arabian Babbler*, trans. Jeffrey Bussolini (Minneapolis: Minnesota University Press, 2021); Charles Stépanoff and Jean-Denis Vigne, eds., *Hybrid Communities: Biosocial Approaches to Domestication and Other Trans-Species Relationships* (New York: Routledge, 2019).

In these margins or borderlands, what is at stake is the ways in which certain species can or cannot participate in different regimes at different times and thus move across categories. And more than that: what is at stake is the continued possibility of this categorial circulation, of the emergence of various positional interactions. Just like the pigs of Ifugao, whose effective participation in different rituals is predicated on their movements back and forth between the differentiated spaces of the house and the forest, crop wild relatives can only retain their usefulness if they have the continued ability to tack back and forth between regimes of wildness and of domestication. And to do so, they must never be reducible to an exhaustive and definitive knowability that would signal that their continued evolution has come to an end. Crucially, crop wild relative conservation is not merely interested in existing diversity, but in the continued processes by which such diversity comes to be – part of the work needed to make these plants into coveted resources must be left to nonhuman ingenuity. As Riordan and Nabhan note in their review of emerging trans situ forms of crop wild relative conservation, "the conservation and study of CWR genetic diversity are best accomplished in situ in the native environments where species continue to coevolve with their biotic associates," and ex situ conservation is a less desirable alternative made necessary by "threats from climate change, land use disruptions, political unrest, and warfare."[112]

This continued reliance on marginal processes is most apparent in the literature signalling that the problem of trait introgression (the transfer of genes from one species into the gene pool of another through repeated backcrossing of hybrids with parent species) goes both ways. While potential assisted gene flow from wild relatives to domesticated species is by and large regarded as an unmitigated good, many biologists are increasingly uneasy about the possibility of reverse flows, especially spontaneous introgression from GM crops to wild relatives. While Ellstrand notes that "[c]rop-wild trysts may have beneficial effects," notably in establishing "unintended repositories of crop alleles that are unavailable in ex situ germplasm collections" (that is, in the bodies of wild species),[113] the threats inherent to crop-to-wild gene flow have been well-documented. They include genetic swamping, selective sweep, and genetic assimilation,

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[112] Riordan and Nabhan, "Trans Situ Conservation," 2388.

[113] Norman C. Ellstrand, "Does Introgression of Crop Alleles into Wild and Weedy Living Populations Create Cryptic in Situ Germplasm Banks?," *Molecular Ecology* 27, no. 1 (1 January 2018): 38–40, 38.

processes which disrupt the distribution of strength and weakness previously found among wild relatives:

> On one hand, if the transgenic alleles will increase the fitness, the individuals in CWR populations that carry the transgenes will out-compete other individuals in the populations. [...] However, if the transgenes reduce fitness, the individuals in CWR populations that carry the transgenes will become less fit or less adaptive to the particular environments in which the populations occur, compared to other individuals that do not have the transgenes in the populations.[114]

The anxieties generated by the possibility of such introgressions show that a full extension of domesticated traits or behaviour to wild relatives runs counter to the goals of crop wild relative conservation. Should the margins in which wild and domesticated relatives meet and engage be swallowed up entirely by domestication processes, and integrated into the sameness of agro-industrial landscapes, any benefits that could be reaped from wild relatives would eventually dry up and disappear. The project therefore contains in itself the necessity to never reach its full extension, since the enterprise of creating a climate change-proofed agriculture could not maintain itself without a continued fostering of the margins in which crop wild relatives proliferate.

4. Neolithic Ethics and Poisoned Milieus

This tension, inherent to any large-scale project of crop wild relative conservation, between an ever-expanding colonisation of interspecies creativity and the preservation of the very margins from which new domestication partners must be sourced, provides the ground for a more speculative approach of what is at stake in these practices. This approach acknowledges the potential emergence of interspecies processes diverging from hegemonic domestication narratives, and unsettling previously unquestioned modes of relating.

As I have shown over the two preceding sections, crop wild relative conservation relies on the production of a series of novel or re-emerging achievements both inside and outside of the experimental spaces in which these plants are conserved and bred. These

[114] Bao-Rong Lu, "Introgression of Transgenic Crop Alleles: Its Evolutionary Impacts on Conserving Genetic Diversity of Crop Wild Relatives," *Journal of Systematics and Evolution* 51, no. 3 (1 May 2013): 245–62, 254.

interspecies achievements, however, coaxed from long-separated relatives in controlled quasi-laboratory settings, are not merely grounds for celebrating a turn, in crop breeding and in conservation biology, towards a more expansive ontology of relational life forms. Indeed, in studying any form of experimental event, especially those arrived at through asymmetrical collaborations, we do well to turn once again to the work of Isabelle Stengers, and of those who have drawn on it. Her repeated insistence on designating certain modes of scientific and economic production as magical is of particular interest here. Stengers' use of the term is always a strategic one; she and Philippe Pignarre were not merely indulging in metaphorical play when speaking of "capitalist sorcery," but "were also pointing to capitalism as able to profit from any opportunity, to turn any lack of imagination, care or attention into its advantage, in brief as a master in surprising its opponents, undermining their positions and producing their disarray and impotence."[115] Naming processes of capitalist and scientific capture as ritual operations allows Stengers to redirect her attention from the question of truth to that of the politics of knowledge. What matters when disentangling those politics is the efficacy of a theory, a practice, or a set of economic relations – the craft by which any of them create subjectivities and sustain constructions. Reframing the problem of modernity and its destructive processes in terms of craft means that one must take seriously both the ways in which contemporary practices have been enrolled by efficacious capture mechanisms *and* the ways in which practitioners craft their own negotiations with these mechanisms, practice their own efficacious magic. The goal then is not to demystify or diagnose forms of alienation or power, but to discriminate finely between the types of crafts that can foster care and those which do not.

Approached from this angle, the practices enabling the collection, conservation and breeding of crop wild relatives, at the Millennium Seed Bank and elsewhere, can be said to take place in what Stengers would call an "insalubrious, infectious milieu"[116] – one in which scientists have become addicted to a "critical demystification" in which their activities can be framed as the uncomplicated continuation of well-defined practices dealing with pre-existing categories of agents.[117] This is particularly apparent when it comes to the dominant rhetoric used in crop wild relative literature, which relies on an

[115] Isabelle Stengers, "Experimenting with Refrains: Subjectivity and the Challenge of Escaping Modern Dualism," *Subjectivity* 22, no. 1 (1 May 2008): 38–59, 55.
[116] Stengers, "Reclaiming Animism."
[117] Stengers, *In Catastrophic Times*, 146.

explicit genealogical link between emergent practices into unbroken histories of domestication. Vernon Heywood et al., for instance, paint a very succinct picture of this progression:

> From the beginnings of agriculture, when the first crops originated, natural crossing between wild species and the crops occurred and subsequently farmers both consciously and unconsciously employed wild species as a source of genetic material to develop and improve the quality and yield of crops through traditional breeding methods.[118]

The main break identified by the authors is the "explicit recognition" of their importance at the beginning of the twentieth century. Many other articles open with a recapitulation of the incremental erosion of genetic diversity in plants through domestication, which is another strategy for creating linearity.[119] As Swanson, Lien and Ween remind us, "stories told about domestication have served to naturalize and justify a specific and dominant way of life, and […] have become political tools in their own right."[120] But focusing merely on a supposedly linear and logical continuation of domestication practices, rather than attending to the patchiness of the various processes conservationists are experimenting with, is a pathway to naturalising a set of political and ethical relations whose continuation is much less assured than this storying would suggest.

This is why I have attempted an alternative reading of crop wild relative conservation and use as a renegotiation of domestication in a profoundly disturbed context. As I argue throughout this thesis, conservation biology is a diplomatic, cosmopolitical exercise in negotiating with or alongside endangered species whose outcomes are highly contingent, local, plural forms of appeasement and survival. I have highlighted the localised practices that scientists and pre-breeders must engage in, the hunting expertise that they must develop, and the positional quality of the wildness and domesticity of crops and their relatives to show that this conservation proposal contains

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118 Vernon Heywood et al., "Conservation and Sustainable Use of Crop Wild Relatives," *Biodiversity in Agricultural Landscapes: Investing without Losing Interest* 121, no. 3 (1 July 2007): 245–55, 245.

119 See for instance Emily Warschefsky et al., "Back to the Wilds: Tapping Evolutionary Adaptations for Resilient Crops through Systematic Hybridization with Crop Wild Relatives," *American Journal of Botany* 101, no. 10 (October 2014): 1791–1800; Dempewolf et al., "Past and Future Use"; Zhang et al. "Back into the Wild."

120 Heather Anne Swanson, Marianne E. Lien, and Gro Ween, "Introduction: Naming the Beast – Exploring the Otherwise," in *Domestication Gone Wild: Politics and Practices of Multispecies Relations*, ed. Heather Anne Swanson, Marianne E. Lien, and Gro Ween (Durham: Duke University Press, 2018), 2.

the potential to foster alternative trajectories, sometimes in opposition with its own rhetorical overtones.

Studying and treating domestication as progress creates, as Tsing emphasises, a set of convenient "just-so" stories that teleologically link domestication with the technological innovations it is supposed to have enabled.[121] Such a methodological premise serves to obscure a variety of other arrangements (as she calls them) entered into by humans and nonhumans, and which have existed and still exist at the margins of the type of domestication specific to emerging nation-states and expanding European empires. This is why the processes of collecting and attempting to study crop wild relatives hold such intriguing potential for revitalising a richer variety of templates for interspecies interaction. Replaying capture and taming processes, as Carpentier and his team or Tamrat and his co-authors are doing, does not inevitably lead to the repetition of progress narratives; these practices also play with types of weediness, cohabitation, marginality and wildness that have been extirpated from the standardised plantations practices I opened this chapter with. Suggesting that this particular practice contains at least the possibility of an alternative agricultural system, another kind of world or nature, might seem too grandiose a mandate for the Crop Wild Relatives Project or any other instance of crop wild conservation. But it is worth noting that the idea of such a mandate has been explicitly seeded by scientists writing on the subject, as exemplified by Brummer et al.:

> Beyond changes in management or the use of alternative crops in conventional systems, entirely new systems must also be developed. On the basis of findings in ecology and agronomy, wholesale changes in farming methods have been proposed – for example, the development and implementation of perennial polycultures that closely mimic natural ecosystems. These agricultural systems would have more in common with native prairies than industrialized monoculture systems. In addition to increased productivity, these systems could enhance ecosystem services, such as soil carbon and nutrient sinks, erosion control, and wildlife cover. Plant breeders have a major role to play in making these systems functional, by domesticating (or re-domesticating) key species.[122]

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[121] Anna Lowenhaupt Tsing, "Nine Provocations for the Study of Domestication," in *Domestication Gone Wild: Politics and Practices of Multispecies Relations*, ed. Heather Anne Swanson, Marianne E. Lien, and Gro Ween (Durham: Duke University Press, 2018), 237.

[122] Brummer et al., "Plant Breeding for Harmony," 565.

This is one possible future for crop wild relative conservation. But beyond facilitating such changes in the structure of contemporary agricultural systems, another challenge for conservationists and pre-breeders alike could be to embrace their role in crafting liveable alternatives to plantation ecologies and progress narratives. This is the provocation I close this chapter with: asking whether crop wild relative conservation might be brought into what Stengers, drawing on Deleuze and Guattari, calls rhizomatic connections to other types of craft, and whether doing so might open the possibility of slipping the noose of rational pigeonholing and of the belief in a scientific independence from emerging biosocial developments.[123] A more explicit acknowledgement of the cosmological frame that could be applied to the ambiguous scientific practices of hunting, taming and farming I have discussed in this chapter might open up an understanding of crop wild relative conservation as a diplomatic discipline, and as one which deals with the invisible and the uncertain. This might be a welcome pharmakon for unpoisoning an ecology of relations guided by a calculus of usefulness and fungibility, and for remaking the milieu required for crop wild relatives to continue *existing* rather than being put to merely instrumental use.

In such a remade milieu, the arrangements between human and nonhuman actors could be modelled on templates that exceed narrow definitions of what useful traits are and how they are to be transferred. Many possible speculative trajectories would be opened by such a project. In his 2016 book *Les diplomates*, in which he analyses the geo- and ethopolitics that emerge around the reappearance of wild wolf populations in France, Baptiste Morizot describes the possibility of an "aneolithic ethics" of influence rather than control, one that would give up on forms of interspecies diplomacy informed by the origin myth of domestication as the basis of care and control.[124] His proposal is not without similarities with that of Paul Shepard's call to "come home to the Pleistocene" or Tsing's focus on "Holocene resurgences" as the constitution of liveable ecologies after disturbances.[125] These positions are certainly conflicting, and sometimes troubling in their apparent search for a purer origin of human-nonhuman relations, but it is interesting to bring them into conversation with the undercurrents of crop wild relative

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[123] See Stengers, "Reclaiming Animism."

[124] Baptiste Morizot, *Les Diplomates. Cohabiter Avec Les Loups Sur Une Autre Carte Du Vivant* (Marseille: Wildproject, 2016), 203.

[125] See Paul Shepard, *Shepard, Paul. Coming Home to the Pleistocene* (Washington, D.C.: Island Press, 1998) and Tsing, "A Threat to Holocene Resurgence."

discourse. While it is too early to make a definite statement about where the current development of the field will lead conservation biology, it seems clear that scientists and breeders are currently searching for historical anchor points to connect their practices to, and perhaps let them branch in an alternative direction. Even their most linear narratives can be read as an attempt – as fraught and partial as the assisted migration cosmologies that closed the previous chapter – to weave themselves into a history that is yet to be crafted, remade, re-membered.

Crop wild relative conservation, ultimately, highlights how crucial contemporary processes of domestication are, and how crucial it is to name them as such: they stage and reprise practices that do not only enrol nonhuman bodies and capabilities, but also diverging and conflicting concepts of what domestication itself is, should be, or could become. In so doing, they enact and re-enact interspecies politics, providing glimpses of alternative pathways even as they serve hegemonic industrial and economic aims. This is a drama played out at many scales and in many places, and crop wild relatives are one of the many loci where this currently unfolding future history can be studied.

Chapter 4.
"The rapidly changing ocean of the future": The Assisted Evolution of Corals

> "[…] 'assisted reproduction', as it is characterized today, ceases to be categorically separate from any other kinds of reproduction. All reproduction reveals itself as, in a sense, 'surrogate'."
>
> — Lewis, "Cyborg Uterine Geography: Complicating 'Care' and Social Reproduction".

I will now turn to my final case study, the assisted evolution of corals – a radically transformative conservation practice that aims to future-proof these enigmatic life forms threatened by climate change. Assisted evolution (re)combines several elements characteristic of both the preceding case studies: the acclimatising ambitions of assisted migration and the reproductive technologies used in crop wild relative breeding converge in the rearing tanks of the Australian Institute of Marine Science (AIMS), albeit with several significant transmutations that make it impossible to reduce the practice of assisting coral evolution to either horticultural or agricultural concerns. In this chapter, I will trace the emergence of assisted evolution in endangered species conservation, starting with contested attempts at genetic rescue and their gradual shading into assisted evolution proper, conducted in both amphibian and coral conservation. I will go on to discuss how the nature of these practices – more akin to engineering than experimental science – render corals as potential model organisms and risk reducing them to manipulable processes and genetic markers.

This critique, however, will have to be nuanced in light of the complex push and pull of entanglement and separation, responsibility and independence that scientists working on assisted evolution are trying to foster. The AIMS might be a reductionist laboratory space, but it also allows for the emergence of corals as complex combinations of different types of evolutionary processes and reproductive modes, and as beings able to function both as plants and animals. Ultimately, I propose to read the interventions of assisted evolution as fostering the possibility of surviving not extinction itself but rather the social and metabolic atomisation that makes recovery after extinction events difficult or impossible; as such, it represents one possible model for denaturalising the complex inter- and intraspecies work of survival and kinship.

I. The Rise of Assisted Evolution

1. Genetic Rescue and Selective Breeding

The issue of adaptation has always animated discussions around the practice of captive breeding in zoos and botanic gardens, at least since the integration of these practices into conservation efforts through links to in situ projects, the establishment of Species Survival Plans by the American Association of Zoological Parks and Aquariums in the 1980s, and their attendant need for master plans, studbooks and the coordination of breeding procedures between zoos.[1] Anxieties around captive breeding have converged around several distinct but related focal points: the problem of keeping populations as unchanged as possible, the issue of excessive habituation to captivity and human closeness, and the question of how to re-adapt individuals slated for reintroduction into wild habitats. As Carrie Friese points out, Species Survival Plans already fulfill the goal of "selectively breed[ing] individuals in the captive population in order to maximize genetic diversity."[2] But zoo breeders have also historically grappled with anxieties about how to breed populations "without compromising the viability of the population or changing its characteristics,"[3] all while negotiating the push and pull of inevitable and necessary habituation and the desire to keep animals as "untainted" by human sociability as possible.[4] Both these issues have been variously problematised, for instance in zoo-biological literature engaging with the inevitable incorporation of human caretakers into an animal's perceptive and social world,[5] or more recent scholarship about the dangers of overlooking behavioural aspects in favour of genetic population viability, which leads

[1] On this topic, see for instance Donahue and Trump, *The Politics of Zoos*; Baratay and Hardouin-Fugier, *Zoo*.

[2] Friese, *Cloning Wild Life*, 31.

[3] Torjörn Ebenhard, "Conservation Breeding as a Tool for Saving Animal Species from Extinction," *Trends in Ecology & Evolution* 10, no. 11 (1 November 1995): 438–43, 438.

[4] As some of them note, "human-induced changes are often an unexpected, unplanned and detrimental side effect of human activities like captive breeding and hand-feeding wild animals. These changes can affect the success of conservation strategies, and embracing the individual approach by conserving the full range of temperaments is likely to play an important role in animal conservation." (P. T. McDougall et al., "Wildlife Conservation and Animal Temperament: Causes and Consequences of Evolutionary Change for Captive, Reintroduced, and Wild Populations," *Animal Conservation* 9, no. 1 [1 February 2006]: 39–48, 40)

[5] The Swiss zoo director Heini Hediger has written several seminal studies on the topic; see for instance Heini Hediger, "Man as Social Partner of Animals and Vice Versa," *Symposium of the Zoolological Society of London*, no. 14 (1965): 291–300.

to the production of animals proving to be virtually clueless when released back into the wild.[6] These discussions all circle around a question sometimes unacknowledged in conservation biology itself, namely the role of ex situ breeding in selecting not only for certain genes but also for certain traits relating to behaviour, plasticity, and adaptability. Moreover, they bring with them debates about whether such selection might not be necessary in order to mitigate the effects of captivity, which cuts zoo animals off from the co-constituting ebb and flow of predatory, commensal, parasitic or symbiotic relationships.

The mandate to breed endangered animals in captivity met with enthusiasm-dampening criticism from several biologists throughout the 1990s.[7] But in the context of increased human-induced introductions of pests and pathogens and the catastrophic destabilisation of climates and habitats, selective breeding has more recently made a comeback in zoo-biological literature. Venesky et al., for instance, state that:

> When species are unable to survive in their natural habitat because of an introduced pathogen or herbivore, conservation efforts, such as captive breeding, are often used to reduce the threat of extinction. The eventual introduction of captive-bred individuals to their natural habitat or their translocation to another area thought to be sufficient habitat is an inherent element of captive breeding programs. Artificial selection in captive breeding programs is often an important tool because natural selection may not occur fast enough to protect hosts from rapid exposure to novel pathogens or herbivores[.][8]

Genetic rescue is not an unprecedented practice in conservation biology. The term "rescue effect" was coined in 1977 to describe the lowering of extinction risks of a given population after immigration, and further studies established the genetic effects of these population movements, distinguishing genetic rescue from demographic rescue and providing "empirical evidence that the genetic contribution of immigrants can cause a

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[6] A problem explored, for instance, in Matthew Chrulew, "Saving the Golden Lion Tamarin," in *Extinction Studies: Stories of Time, Death, and Generations*, ed. Matthew Chrulew, Deborah Bird Rose, and Thom Van Dooren (New York: Columbia University Press, 2017).

[7] See Andrew E. Bowkett, "Recent Captive-Breeding Proposals."

[8] Matthew D. Venesky et al., "Selecting for Tolerance against Pathogens and Herbivores to Enhance Success of Reintroduction and Translocation: Tolerance against Pathogens and Herbivores," *Conservation Biology* 26, no. 4 (August 2012): 586–92, 587. The necessity of utilising zoos as partners in conservation projects by expanding captive breeding programs has also been the object of popular defences; see for instance Colin Tudge, *Last Animals at the Zoo: How Mass Extinction Can Be Stopped* (Washington, Covelo, London: Island Press, 1992).

further increase in abundance."[9] While genetic rescue, defined by Bell et al. as the "decrease in population extinction probability owing to gene flow, best measured as an increase in population growth rate,"[10] is still a rarely used conservation strategy, it has been discussed in the literature for about two decades, and the introduction of individuals into a population threatened by genetic bottleneck has been experimented with at least since the 1990s.

These attempts map neatly onto a shift in conservation biology that could be described in biopolitical terms, away from the reproduction of individuals and towards an increased attention to "population fitness," that is the management of the various factors ensuring that a population as a whole is healthy and robust enough to continue reproducing and withstand potential environmental changes. As the example of serious issues with cheetah populations both in captivity and in the wild has strikingly illustrated, population fitness cannot be predicated on numbers alone – low genetic diversity is a serious issue in conservation biology, and the dwindling of said diversity can lay the groundwork for the disappearance of a population, or the extinction of a species, long before its numbers are reduced enough to tilt over into genetic bottleneck.[11] In conservation genetics, what matters most to the survival of the species is the future diversity hoarded and maintained within the bodies of its members, the breadth of the possibilities among which climate change or habitat loss will select traits that may or may not be beneficial. The statistical management of populations is ruled by the goal of maximising this diversity, and the beneficial mutations that can result from it. This trading of a form of sovereign power, exerted over a nature that must be subdued, for the technological management of species and populations that must be multiplied and sustained, has consistently underpinned developments in the management of captive populations in zoos and botanic gardens. In this, zoos in particular have enacted the transformation of power diagnosed by Foucault in *The Will to Knowledge*, from the sacrificial sovereign mandate to *make die* and *let live* to the productive regulatory

[9] Donovan A. Bell et al., "The Exciting Potential and Remaining Uncertainties of Genetic Rescue," *Trends in Ecology & Evolution* 34, no. 12 (December 2019): 1070–79, 1070.
[10] Bell et al., "The Exciting Potential," 1071.
[11] See for instance S. J. O'Brien et al., "The Cheetah Is Depauperate in Genetic Variation," *Science* 221, no. 4609 (29 July 1983): 459–62.

interventions that exert power over life by normalising and optimising a variety of biological processes.[12]

In this context, the idea of infusing genetically endangered populations with "immigrant" individuals imported in order to make available the genetic possibilities they contain has increasingly come to be considered as a reasonable strategy. One of the most frequently discussed and publicised cases is that of the Florida panther; a newly discovered remnant population of this species was supplemented, in 1995, with eight female pumas from Texas, a subspecies family reunion whose result was that "panther numbers increased threefold, genetic heterozygosity doubled, survival and fitness measures improved, and inbreeding correlates declined significantly."[13] Other adjacent projects have been conducted in the past years, such as the breeding of blight-resistant American chestnut trees in 2014, and the ongoing restoration of genetic diversity to a group of black-footed ferrets, rediscovered after they were believed to be extinct, by using samples of unrelated individuals banked at the Frozen Zoo® at San Diego Zoo.[14]

Another proposal for selectively breeding resistance into endangered populations is gathering momentum in amphibian conservation. The virulent disease chytridiomycosis, caused by a fungal pathogen (*Batrachochytrium dendrobatidis*, often shortened into Bd) and intensely dangerous to frog populations worldwide, was discovered in 1988 and characterised as an important factor in the ongoing sixth mass

[12] See Michel Foucault, *The Will to Knowledge*, trans. Robert Hurley, vol. 1, 4 vols, The History of Sexuality (London: Penguin Books, 1998). As mentioned in my overview of the relevant literature in Chapter 1, this specific analysis of shifts from one power formation to another has been taken up in a wide range of critical scholarship about the management, treatment and scientific study of animals; see for instance Nicole Shukin, *Animal Capital: Rendering Life in Biopolitical Times* (Minneapolis: Minnesota University Press, 2009). For a comprehensive overview of the biopolitical transformations of the zoo, see for instance Chrulew, "Managing Love and Death at the Zoo."

[13] Warren E. Johnson et al., "Genetic Restoration of the Florida Panther," *Science* 329, no. 5999 (24 September 2010): 1641–45, 1641.

[14] The last extant population of black-footed ferrets was captured in Wyoming in 1987 and has since then been bred in captivity and reintroduced. The use of genetic material held at the Frozen Zoo has been recently proposed to revitalise this small population (see Samantha M. Wisely et al., "A Road Map for 21st Century Genetic Restoration: Gene Pool Enrichment of the Black-Footed Ferret," *The Journal of Heredity* 106, no. 5 (2015): 581–92). The anthropologist Adrian Van Allen has traced the distributed networks of reproductive technologies, captive breeding techniques, behavioural reconditioning and wildlife vaccines necessary for orchestrating the reweaving of black-footed ferrets into future landscapes. She concludes that "[a]s technologies migrate from human biomedical contexts into the 'feral' landscape of biodiversity conservation, they carry with them the imaginaries of potential to both literally and figuratively reproduce different futures. These futures are populated with ferrets engineered in labs and used to reconstruct – perhaps more precisely to resurrect – an idea of the iconic American prairie, one re-engineered to be untouched by extinction, habitat loss, plague, and agricultural expansion." (Adrian Van Allen, "Resurrecting Ferrets and Remaking Ecosystems," *Anthropology News* 60, no. 3 (1 May 2019): e53–60, e60)

extinction event in 2008.[15] Amphibians, the "multipurpose sentinels of environmental health" whose "moist, well vascularized skin places them in intimate contact with their environment,"[16] are particularly vulnerable to the interference in oxygen exchange and osmoregulation caused by the colonisation of their permeable interface with the world by the deadly fungus, which lives and reproduces on their skins. Their physiological fragility, combined with the creation, by human mobility, capitalist flows of extraction and trade, and the tightening of temporal nets across the globe, of a new Pangaea for seasoned and resilient travellers such as fungal pathogens, makes them first in line for succumbing to new pandemics.[17] The situation is dire: Scheele et al. "conservatively report that chytridiomycosis has contributed to the decline of at least 501 amphibian species (6.5% of described amphibian species). This represents the greatest documented loss of biodiversity attributable to a pathogen and places *B. dendrobatidis* among the most destructive invasive species […]."[18] But frogs can rally when treated in captivity, and a host of mitigation methods has been tentatively put forward: introducing commensal bacteria that might help frogs fight off the pathogen, translocating vulnerable populations, removing Bd host species from the environment, treating frogs ex situ chemically or physically (and possibly releasing them into the wild once cleared), or selecting for resistance in captive colonies.[19] This last strategy has been pioneered by the Voyles Lab at the University of Nevada and the Center for Species Survival at the Smithsonian Institution; Jamie Voyles and Brian Gratwicke, working respectively at the former and the

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[15] See respectively Lee Berger et al., "Chytridiomycosis Causes Amphibian Mortality Associated with Population Declines in the Rain Forests of Australia and Central America," *Proceedings of the National Academy of Sciences* 95, no. 15 (21 July 1998): 9031 and D. B. Wake and V. T. Vredenburg, "Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians," *Proceedings of the National Academy of Sciences* 105, no. Supplement 1 (12 August 2008): 11466–73.

[16] Wake and Vredenburg, "Are We in the Midst of the Sixth Mass Extinction?," 11467.

[17] The authors who coined this phrase were already mentioned in the context of assisted migration, but it is worth emphasising that their argument focuses more specifically around the question of infectious diseases: "The unprecedented lethality of a single disease affecting an entire vertebrate class highlights the threat from the spread of pathogens in a globalized world. Global trade has recreated a functional Pangaea for infectious diseases in wildlife, with far-reaching impacts on biodiversity (this study), livestock, and human health." (Scheele et al., "Amphibian Fungal Panzootic," 3).

[18] Scheele et al., "Amphibian Fungal Panzootic," 3.

[19] On bacteria introduction, see Matthew H. Becker et al., "Composition of Symbiotic Bacteria Predicts Survival in Panamanian Golden Frogs Infected with a Lethal Fungus," *Proceedings of the Royal Society B: Biological Sciences* 282, no. 1805 (22 April 2015): 20142881. On the removal of host species from the environment, see Douglas C. Woodhams et al., "Mitigating Amphibian Disease: Strategies to Maintain Wild Populations and Control Chytridiomycosis," *Frontiers in Zoology* 8, no. 8 (2011): 1–23. On chemical treatments, see Ben C. Scheele et al., "Interventions for Reducing Extinction Risk in Chytridiomycosis-Threatened Amphibians: Reducing Extinction Risk in Amphibians," *Conservation Biology* 28, no. 5 (October 2014): 1195–1205. On selecting in captive colonies, see Venesky et al., "Selecting for Tolerance against Pathogens."

latter, have been involved in a study of captive populations of Panamanian Atelopus frogs which states, among other conclusions, that "captive populations will be an invaluable asset for breeding resistant frogs that can reduce Bd infections or tolerant frogs that can limit damage caused by infection."[20]

These emerging practices exemplify how conservationists, in the early twenty-first century, have responded to the growing urgency of environmental threats to species survival with genetic and breeding techniques that intervene into biological processes to a degree previously unimaginable in conservation biology.

2. Human-Assisted Evolution in Coral Conservation

Assisted evolution, a term which has recently branched off from earlier literature calling it facilitated adaptation, is the heir apparent to the pioneering projects I have outlined above and represents a further leap in the practice of breeding endangered wild species toward survival. While projects such as the revitalisation of the Florida panther make use of a different subspecies, resulting in a potential ontological transformation of the host species, they are also involved in a stabilising discourse to safeguard the distinction between natural processes and artificial intervention. In this, conservation biology still replicates the drive to purify the realms of nature and of culture that has been identified by Latour as one of the key practices that constituted scientific modernity.[21] The issue of naturalising a potential hybrid of supposedly natural processes and human intervention was specifically raised during the controversies surrounding the release of the eight Texan pumas, and how it would be answered was an important point in determining whether or not this genetic rescue should be attempted. Pimm, Dollar and Bass conclude their summary of the debate thus:

> Finally, if one introduces cats from Texas into Florida, will their progeny still be the Florida panther and so still be deserving of protection as a federally listed endangered species? The Fish and Wildlife Service determined that such individuals would still qualify before releasing the Texas cats.[22]

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[20] Carrie H.R. Lewis et al., "Conserving Panamanian Harlequin Frogs by Integrating Captive-Breeding and Research Programs," *Biological Conservation* 236 (August 2019): 180–87, 185.

[21] See Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge, Massachusetts: Harvard University Press, 1993), 10-11.

[22] Stuart Pimm, Luke Dollar, and O.L Bass Jr, "The Genetic Rescue of the Florida Panther," *Animal Conservation* 9 (1 May 2006): 115–22, 117.

Friese has also touched upon the Florida panther debate in *Cloning Wild Life*, where she maps the debates concerning the value of hybrids in conservation. She notes that the acceptability of panther hybrids in this instance hinged on the "scientific evidence that the Florida panther had at one point in time dwelled across North, Central, and South America in coexistence with the puma. Thus, the two species have a history of cohabitation and hybridization." The context in which the cloning projects Friese examines have emerged is one in which hybridisation is only acceptable if it recreates a state of affairs that existed (or at least can be imagined to have existed) before human interference, and it "cannot to be used to create something new through human intervention."[23]

But things have been changing in conservationist discourse, purifying strategies notwithstanding, and conservation biology has seen the recent rise of proposals decidedly less embarrassed about genetic manipulation. This shift can be read, for instance, in a short comment article published in *Nature* in 2013 and titled "Gene Tweaking for Conservation." The authors "weigh up the pros and cons of using genetic engineering to rescue species from extinction." and outline three possible options: hybridisation with better-adapted populations, direct transfer of alleles from these populations into the genomes of their threatened kin, and the same kind of genetic manipulation, using different species. They conclude that:

> Ultimately, successful facilitated adaptation will require unprecedented collaboration between organismal, ecological and molecular biologists and climate scientists. Biorepositories – such as seed banks, natural history museums and zoological parks, including the Frozen Zoo at San Diego Zoo in California, which houses around 9,000 frozen cell samples from endangered species – will need to be integrated with advances in biotechnology and efforts to explore the genomic mechanisms underlying adaptive traits associated with climate change, catastrophic diseases and so on.[24]

This experimental approach – which, as I have outlined in the first chapter, is enabled by the accumulation of a sufficient quantity of biological material in ex situ repositories – has ultimately led from mentions of facilitated adaptation to talk of assisted evolution, a

[23] Friese, *Cloning Wild Life*, 30

[24] Michael A. Thomas et al., "Ecology: Gene Tweaking for Conservation," *Nature* 501, no. 7468 (26 September 2013): 485–86, 486.

project now stripped of most of the placating connotations of the earlier term. A handful of recently published articles have explicitly called on the marine conservation community to investigate the possibility of "speed[ing] up evolution"[25] in order to mitigate the effects of the catastrophic heat waves of 2016 and 2017, which led to a massive bleaching event in the Great Barrier Reef – not the first of their kind, but certainly among the most destructive to date in this region.[26] In this context of almost hopeless urgency, a number of marine scientists working in coral conservation and restoration are in the process of making good on a recently published call for "a series of experiments to determine the feasibility of developing coral stocks with enhanced stress tolerance through the acceleration of naturally occurring processes, an approach known as (human)-assisted evolution […]."[27]

Two marine biologists, the late Ruth Gates and Madeleine Van Oppen, have figured among the main proponents of coral assisted evolution (along with Mary Hagedorn, who has also conducted recent attempts at cryoconserving coral sperm and larvae), claiming that it "is critical to build a biological tool box now that can be used to enhance resilience and mitigate the impacts of disturbance, with the goal of sustaining human services and biodiversity in the rapidly changing ocean of the future."[28] The proposal they have co-drafted is at least four-fold, combining different levels of intervention and therefore different types of potential transformations.[29] Their "biological tool box" is structured around the following evolutionary processes:

[25] A term used by Madeleine Van Oppen in some interviews (quoted for instance in Nerissa Hannink, "Breeding Baby Corals for Warmer Seas," *Pursuit* [blog], 26 March 2019.).

[26] Higher ocean temperatures are one of the greatest threats to coral reefs worldwide, and back-to-back heatwaves are becoming increasingly frequent (on that topic, see for instance Alexander J. Fordyce et al., "Marine Heatwave Hotspots in Coral Reef Environments: Physical Drivers, Ecophysiological Outcomes, and Impact Upon Structural Complexity," *Frontiers in Marine Science* 6 (2019): 498). "On coral reefs, severe heatwaves trigger episodes of mass bleaching, which occur when the relationship between corals and their photosynthetic symbionts (zooxanthellae, *Symbiodinium* spp.) breaks down, turning the coral pale. Bleached corals are physiologically damaged and nutritionally compromised, and they can die if the bleaching is severe and the recovery time of their symbionts is prolonged." (Terry P. Hughes et al., "Global Warming Transforms Coral Reef Assemblages," *Nature* 556, no. 7702 [1 April 2018]: 492–96, 492). On the 2016 Great Barrier Reef bleaching event, see for instance Terry P. Hughes et al., "Global Warming and Recurrent Mass Bleaching of Corals," *Nature* 543, no. 7645 (1 March 2017): 373–77.

[27] Madeleine J. H. Van Oppen et al., "Building Coral Reef Resilience through Assisted Evolution," *Proceedings of the National Academy of Sciences* 112, no. 8 (24 February 2015): 2307–13, 2307.

[28] Van Oppen et al., "Building Coral Reef Resilience," 2312.

[29] On coral cryopreservation, see for instance Mary Hagedorn and Rebecca Spindler, "The Reality, Use and Potential for Cryopreservation of Coral Reefs," *Advances in Experimental Medicine and Biology* 753 (2014): 317–29.

> (i) stress exposure of natural stock to induce preconditioning acclimatization (i.e., within generations) and transgenerational acclimatization (i.e., between generations) through epigenetic mechanisms sensu stricto; (ii) the active modification of the community composition of coral-associated microbes (eukaryotic and prokaryotic); (iii) selective breeding to generate certain genotypes exhibiting desirable phenotypic traits; and (iv) laboratory evolution of the algal endosymbionts (*Symbiodinium* spp.) of corals through mutagenesis and/or selection (i.e., evolution after the generation of variability).[30]

The third process in this list – selective breeding – has received "virtually no attention in coral reef conservation," according to the authors, "despite its clear relevance," and it forms the main focus, novelty and strength of their proposal.[31] The authors propose the mixing of gene pools both within species in order to select for resilient variants and across different but closely related species in order to create more resistant hybrids. As they point out, "a range of coral species are known to hybridize with other species in the wild"; here, the hybrid is not construed as a threat to established taxonomies and conservation policies whose status must be immediately stabilised or justified, but as an interesting opportunity to maximise fitness in dangerously disturbed environments.[32]

The work to create a coral "bred for the future" is not merely theoretical, but already well underway in several laboratories around the world.[33] One such place is the National Sea Simulator, a facility of the AIMS located in Townsville, Queensland, where two projects in intra- and inter-specific hybridisation are currently being conducted. The former, helmed by Line Bay, has seen *Acropora millepora* corals flown in from northern Queensland where they had survived the 2016 and 2017 heatwaves – the ironies of shipping endangered species by air like so much precious cargo is not confined to attempts at assisted colonisation[34] – and tested for increased heat tolerance. The juveniles resulting from cross-fertilisation with *Acropora millepora* from the middle of the reef have been transplanted to the Great Barrier Reef in July 2019 and the survival rates

[30] Van Oppen et al., "Building Coral Reef Resilience," 2310.
[31] Van Oppen et al., "Building Coral Reef Resilience," 2310.
[32] Van Oppen et al., "Building Coral Reef Resilience," 2310.
[33] Ruth Gates, quoted in *Creating "Super Coral" to Save Dying Coral Reefs*, 2015, https://www.youtube.com/watch?v=DtCDquEYzPE.
[34] See "Coral Makes Rare Charter Flight," *AIMS*, 24 November 2107 and Thom Van Dooren, "Moving Birds in Hawai'i: Assisted Colonisation in a Colonised Land," *Cultural Studies Review* 25, no. 1 (25 September 2019): 41–64.

of various crossbreeds are currently being monitored, in an early test of the feasibility of the project on a larger scale.[35]

The interspecific hybridisation project, conducted under the direction of Madeleine Van Oppen, consists in breeding several different pairs of coral species in order to monitor the traits potentially inherited by their offspring. To date, Van Oppen's team has published the results of the reciprocal crossing of two Acropora species pairs – *Acropora tenuis* and *Acropora loripes* on the one hand, and *Acropora sarmentosa* and *Acropora florida* on the other – which resulted in the creation of eight different offspring groups.[36] In order to do this, corals are grown at the Sea Simulator, where they are kept in several separate tanks and closely monitored around their spawning time. This is one of the most critical moments in the process of assisted evolution: when the corals spawn (the timing of which is staggered across the different *Acropora* species involved, necessitating them being quarantined for a few hours to avoid uncontrolled cross-breeding), the sperm and eggs are scooped out of the tanks, taken to the fertilisation room, rinsed out and separated, and divided into different cups, there to await cross-breeding with gametes from the species singled out for hybridisation.[37] After successful fertilisation of the eggs and the colonisation of ceramic plugs by larvae, the new colonies are distributed into rearing tanks, with one half grown at ambient conditions and the other in water warmed up to one additional degree, and with increased acidity.[38] Having been given "something that challenges their biology and will translate to them performing better on the reef," in the words of Ruth Gates,[39] they are then monitored for "survival, recruit size, *Symbiodinium* uptake, and photochemical efficiency," with the observed result that "across all traits measured, hybrids were either equivalent to or more fit than

[35] See "Next Generation Corals Undergo First Field Tests on the Great Barrier Reef," *AIMS*, 2 July 2019.

[36] See Wing Yan Chan et al., "Interspecific Hybridization May Provide Novel Opportunities for Coral Reef Restoration," *Frontiers in Marine Science* 5 (14 May 2018): 160.

[37] "On this November evening, one of Van Oppen's main experiments is to develop new hybrids. The candidates for this night's matchmaking are pale brown chunks of the small, spiky, and ubiquitous corals *Acropora tenuis* and *A. loripes*. Although those coral live side by side on the Great Barrier and other reefs, *A. loripes* spawns several hours after its cousin, effectively keeping the species separate. But Van Oppen can overcome that in the lab by mixing their spawn by hand." (Warren Cornwall, "Researchers Embrace a Radical Idea: Engineering Coral to Cope with Climate Change," *Science*, 21 March 2019).

[38] "Settled recruits were randomized and evenly distributed on 24 tailor-made PVC trays to rear under (1) ambient conditions of 27°C, 415 ppm pCO_2, or (2) elevated conditions of ambient +1°C, 685 ppm pCO_2." (Chan et al., "Interspecific Hybridization," 5)

[39] Gates, quoted in American Museum of Natural History, *Science Bulletins: Super Corals – Understanding the Science*, 2016, https://www.youtube.com/watch?v=Yy--l-P4c8A

at least one parent, and none of the hybrids performed worse than both parents."[40] While the authors conclude that hybridisation has no observable negative effects, they close by pointing toward the need for demonstrating "that the risk of this strategy is low by showing that the fitness of later generations remains equal or superior to that of the parental species in the wild" before it can be considered as a viable conservation option.[41] The assisted evolution of corals remains an open and uncertain endeavour in multiplying the pathways of survival for corals in an increasingly hostile environment.

[40] Chan et al., "Interspecific Hybridization," 3 and 11.
[41] Chan et al., "Interspecific Hybridization," 13.

II. Coral Models

Before I come back to the question of what is being multiplied in coral assisted conservation and how, this chapter must first examine the emergence of corals and coral reefs themselves as imaginary and theoretical loci in evolutionary biology, conservation, and a host of other disciplines. The unique situation of these organisms and the communities they form is important for understanding what beings and abilities are created in the experimental tanks of the AIMS. As I have shown in the previous section, genetic rescue and selective breeding with a view to the assisted evolution of wild species have been attempted in a variety of spaces and for a variety of species. But it is in coral conservation that interspecific hybridisation – alongside other forms of selective breeding – has been conducted most intensively and freely so far. Coral species are subjects particularly well attuned to the goals and needs of the hybrid laboratory spaces that have sprung up in and around conservationist institutions; their physiological, social, and reproductive characteristics allow them to emerge as privileged and surprising partners in this breeding project.

1. Coral Figures

Coral species, and the reefs that they build together, have emerged as one of the sites where Anthropocene practices and discourses are formed, tested, and contested. Stefan Helmreich, building on Haraway's attention to "non-mammalian replicative doings among marine invertebrates,"[42] characterises them as figures that "can attune their human visitors and inquisitors to empirical and epistemological questions of scale and context" and traces the chronology of their successive figurations over the past two centuries.[43] Coral reefs, in the nineteenth and first half of the twentieth century, captured the imagination of naturalists and social theorists as architectural formations bridging geology and biology, past and future. The anthropologist Alfred Kroeber is emblematic of this early focus on the structure formed by reef-building corals in his use of reefs, "a product at once cumulative and communal and therefore social," as a metaphor for the

[42] Donna Haraway, "Foreword," in *Women Writing Culture*, ed. Gary A. Olson and Elizabeth Hirsch (Albany: State University of New York Press, 1995), xi.

[43] Stefan Helmreich, "How Like a Reef: Figuring Coral, 1839–2010," in *Sounding the Limits of Life: Essays in the Anthropology of Biology and Beyond* (Princeton: Princeton University Press, 2016), 49.

culture concept.[44] As Helmreich emphasises, Kroeber and his predecessors were more interested in the superorganic than in the organisms themselves, in reefs as the result of collaborative social labour and in the result of collective agency rather than the processes by which such an agency emerges in the first place.

With the transformations brought by ecological writings such as Rachel Carson's, and the first visual representations of coral reefs such as Jacques Cousteau and Louis Malle's 1956 documentary *The Silent World*, corals would go on to "become interesting not just as architecture, but as animate matter": changes in scientific methods and immersive technologies enabled new kinds of encounters with lively corals, and spurred interest in their fleshy bodies and reproductive transactions.[45] As compound organisms with translocal and distributed spawning behaviour, as well as habitat for a host of other gender-fluid organisms, coral reefs have emerged as a "reminder that sex/gender does not describe a natural hierarchy or binary." which, as Helmreich is careful to emphasise, comes with its own risk of renaturalising and categorising queer relations and modes of being when they are taken as "a sedimented site of literal truths about nonhuman nature."[46] This question has also been explored by Eva Hayward in her ethnographic writing on laboratory cup corals.[47] Cris Vaughan, the PhD candidate who Hayward observes and interviews at the Long Marine Laboratory in Santa Cruz, recasts her own work on the reproductive strategies of cup corals as revealing of the prevalence of a "polymorphous sexuality" among invertebrates. Hayward herself weaves this statement into her queer reading of species – in particular coral species – as embodied impressions of sensuous encounters in the conducive medium of saltwater tanks.

Porous and mutable, coral reefs are not yet done with successive waves of figuration. Helmreich concludes his historical retrospective thus:

> In the figurations of coral I have followed here, I discern a movement from opacity, to visibility, to readability. For Darwin, coral were glimpsed dimly, as bare bone, after death and, if living, through foamy water. For twentieth-century SCUBA diving scientists, coral were best encountered from an immersive, bodied, point of view. And for today's environmentalists, biotechnologists, and would-be coral genomicists, coral are something to be read – for climate change, for potentially patentable genes, for

[44] Kroeber, "The Nature of Culture," cited in Helmreich, "How Like a Reef," 51.
[45] Helmreich, "How Like a Reef," 52.
[46] Helmreich, "How Like a Reef," 55.
[47] See Eva Hayward, "FINGERYEYES: Impressions of Cup Corals," *Cultural Anthropology* 25, no. 4 (November 2010): 577–99.

> representativeness. […] What difference does a figuration of coral make? What successor epistemologies can we imagine settling on and metamorphosing the textual idioms of genomics?[48]

This last question also threads through my analysis of coral assisted evolution, albeit in a slightly different mode, as his reading sometimes skews toward a literary analysis of metaphorical figuration that my own analysis of laboratory practices mostly avoids. In addition to this, coral assisted evolution projects represent one more epistemological transmutation of the field, but they do so by bringing together elements from each of the periods delineated by Helmreich and therefore necessitate a less chronologically linear approach than his. As we will see, the corals grown in the experimental tanks of the Sea Simulator are being manipulated as the carriers of valuable genomes, as fleshy and variously reproducing bodies, but also – and through these manipulations – as the sedimented result of long histories of interspecies collaboration, which must be safeguarded against extinction by putting coral species to work in new and accelerated ways.

2. Reductive Practices

The coexistence of epistemological frameworks in assisted evolution means in particular that any pleasure in the boundary-blurring, "non-mammalian" collaborations taking place within and between corals needs tempering. As Hayward notes, "the corals remained objects of biological and ethnographic research" even as she "experienced epistemological revelry." They were selected, dismembered and sometimes sacrificed in the name of experimental practices – suffering and deaths which her own involvement in routine laboratory work at the Long Marine Laboratory has contributed to.[49] Helmreich too points out the increasing dismemberment of corals into fungible elements, closing his review of coral figurations by identifying one last and recent transmutation of coral bodies, which shift from sedimented bone and lively flesh to genetic code at the beginning of the twenty-first century. The queer utopia of the reef, and the rich multispecies ecosystems it supports, are now under intensified threat, and are considered by many ecologists to be an important canary in the climate change coalmine. At the same time,

[48] Helmreich, "How Like a Reef," 60.
[49] Hayward, "FINGERYEYES," 583.

they have emerged as yet one more frontier to be conquered by biomedical prospecting, as the toxins released by some corals in defence against threats might be of interest in developing drugs to treat cancer and HIV. Both figurations are intimately linked to the rising importance of genomics in coral research, and recent calls for a "Coral Genome Project" have quickly developed into debates as to which coral species could offer the best model and prove the most useful lab rat. In intense debates carried out on the "Coral-list" listserver, both the round, fleshy *Porites lobata* and the genus of branching *Acropora* used in Bay's and Van Oppen's hybridisation experiments at the AIMS have been championed as good model organisms for laboratory research.[50]

This discussion, and the fact that one of the main lab rat candidates has reappeared in assisted evolution, is an important element in understanding the workings of assisted evolution. *Acropora*, "the most widely distributed (and studied) genus in the world," has become a model genus for this particular conservation project, if not yet for coral science as a whole.[51] What Helmreich names when he mentions the rise of coral genomics and biomedical prospecting on coral reefs is the simultaneous reduction of coral to exploitable commodities and to standardised laboratory objects, a shift which Haraway would recognise as a form of reification that "transmutes material, contingent, human and nonhuman liveliness into maps of life itself."[52] She uses maps and models to show how genetic fetishism works in the technoscientific culture of the 1980s and 1990s, more specifically in molecular genetics and biotechnology. Genome mapping encloses the "commons of the body," allowing scientists to "forget" that they are representing only one very specific and reified version of human and nonhuman biology and, in so doing, obscuring a vast array of social and technical relations between various species.[53] As I mentioned in the overview of shifting conservation paradigms that was the main focus of Chapter 1, the molecular turn in biology diagnosed by Haraway and several other science and technology scholars also played out in conservation biology.[54] Genetic science has precipitated a "scalar shift" in conservation, where biodiversity is now increasingly defined at the level of genes rather than that of species or ecosystems, and where

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[50] Helmreich, "How Like a Reef," 58–59.
[51] Helmreich, "How Like a Reef," 59.
[52] Haraway, *Modest Witness*, 135.
[53] Haraway, *Modest Witness*, 147-148.
[54] For an influential example of a Foucauldian approach to molecular biopolitics, see Nikolas Rose, *The Politics of Life Itself* (Princeton: Princeton University Press, 2007). See also Sarah Franklin, "Life Itself: Global Nature and the Genetic Imaginary," in *Global Nature, Global Culture*, ed. Sarah Franklin, Celia Lury, and Jackie Stacey (London: SAGE, 2000).

molecular biology reconfigures the possibilities for commodifying and manipulating wildlife.[55] While Madeleine Van Oppen and Line Bay's research projects are not structured by bioprospecting goals, assisted evolution has nevertheless provided fertile ground for thinking about *Acropora* species as new, representative maps and models of coral bodies and abilities.

As such, coral parents and hybrid offspring appear to be treated as a set of measurable functions and performances when it comes to studying the potential of assisted evolution. In the "proof-of-concept" study that monitored the fitness of interspecific hybrids reared from 2015 on at the AIMS, pains were taken to purify every step of the procedure. Parent colonies collected on Trunk Reef were "isolated in individual tanks to avoid uncontrolled mixing of gametes prior to in vitro crossing" at spawning time, egg-sperm bundles carefully separated and washed, and *Symbiodinium* uptake in the larvae of each offspring group carefully controlled so that each group would only receive symbionts from their parent species.[56] The question asked by the authors of the study is whether hybridisation has any effects of species fitness, defined here as an increase in "genetic variation which can potentially enhance adaptive capacity and release a population from adaptive limits."[57] To answer this question, survival in ambient treatment and elevated treatment (tanks with elevated temperatures and carbon dioxide levels) was monitored by measuring "[f]our phenotypic traits (i.e., survival, recruit size, *Symbiodinium* uptake, and photochemical efficiency) […] in hybrid and purebred offspring as proxies for fitness."[58] The results of this year-long monitoring, which show that hybrids "performed" no worse than purebreds and often better, are documented in extensive tables and graphs in which the different traits of coral biology are dismembered and rendered legible and comparable.

The possibility of separating coral bodies from each other and of observing and measuring how a restricted set of functions –metonymically designating their reproductive success and ability to survive – fare under unfavourable conditions has subsequently led AIMS marine scientists to investigate the genomic underpinnings of heat stress tolerance. While the 2018 study was mainly concerned with phenotypic traits, Van Oppen, Bay and Kate Quigley recently published the results of an analysis in which

[55] Hennessy, "The Molecular Turn in Conservation," 89.
[56] Chan et al., "Interspecific Hybridization," 3 and 5.
[57] Chan et al., "Interspecific Hybridization," 12.
[58] Chan et al., "Interspecific Hybridization," 3.

they "combine phenotypic, pedigree, and genomic marker data" from the interspecific hybrids created by selectively breeding corals from warm and cool locations.[59] Aiming to understand the genetic processes at work in selective breeding and in adaptation to warmer environments, this study responds to the fact that "[i]ncreases in genetic diversity, hybrid vigour and genetic rescue are well-known but inconsistent features of intra- and interspecific hybridization but have not yet been demonstrated in the selective breeding of corals."[60] The authors conclude that selective breeding influences the genetic architecture of the *Acropora spathulata* crosses analysed for the study, that this genomic variation leads to phenotypic changes "to the immunity and stress responses and growth, probably important processes in survival generally," and that these variations are heritable.[61] While this study was conducted on interspecific crosses rather than Van Oppen's hybrids, she and John Oakeshott have mentioned assisted evolution through hybridisation in a commentary article responding to a recently published protocol for editing the *Acropora millepora* genome by using CRISPR gene editing. Noting that several "bioengineering" approaches, among them assisted evolution, have been trialled with success in small-scale laboratory experiments, Van Oppen and Oakeshott add that these projects would benefit greatly from the additional knowledge a technology such as CRISPR gene editing could provide concerning the genetic mechanisms of thermal tolerance, and potentially a host of other coral traits.[62]

Van Oppen and Oakeshott conclude by tempering the hopes of generating resistant coral strains directly and calling for the prioritisation of non-GM conservation approaches, but articles such as this one open up a direct line of communication between assisted evolution and GM projects. It is therefore not surprising that the apparently reifying and instrumentalising techniques of assisted evolution have prompted a number of ethical concerns. Rendering coral bodies as a set of traits, processes and genetic markers that can be intervened into would be read as steps towards "deciding the winners and losers of the Anthropocene, and in so doing, designing and creating the world

[59] Kate M. Quigley, Line K. Bay, and Madeleine J. H. Van Oppen, "Genome-Wide SNP Analysis Reveals an Increase in Adaptive Genetic Variation through Selective Breeding of Coral," *Molecular Ecology* 29, no. 12 (1 June 2020): 2176–88, 2176.
[60] Quigley et al., "Genome-Wide SNP Analysis," 2183.
[61] Quigley et al., "Genome-Wide SNP Analysis," 2184.
[62] See Madeleine J. H. Van Oppen and John G. Oakeshott, "A Breakthrough in Understanding the Molecular Basis of Coral Heat Tolerance," *Proceedings of the National Academy of Sciences* 117, no. 46 (17 November 2020): 28546.

around us *as we want it to be*."[63] This is the tack taken by Karen Filbee-Dexter and Anna Smajdor, who point out that assisted evolution seems fated to reproduce the very interventions that have created the situation it wishes to remediate. If the justification for assisted evolution is based on value judgements about the ecosystem services provided by coral reefs, Filbee-Dexter and Smajdor worry that "[r]ather than changing our resource-hungry approach to nature, assisted evolution confirms and facilitates our relationship with nature as one of consumption and commodification."[64]

3. Engineering Novelty

The argument that assisted evolution may enable the further hypertrophy of human agency and human projects is partly supported by the nature of the experiments conducted to test assisted evolution. These research projects are taking place on what is very new terrain for marine science and coral conservation, and the scientists working on assisted evolution function more as technological innovators than as experimental scientists. This distinction follows the one made by Isabelle Stengers when she says of experimental biochemists – whose work she opposes to the molecular reductionism of experimental physicists – that "[t]echnology here is no longer strongly connected to the power of definition, and is much closer to the usual meaning of diverting something which is already working in order to have it work for you."[65]

The language of design and innovation has crept into the literature on assisted evolution and its cluster of associated studies to a very noticeable degree, and permeates much of the public, popularising discourse of its practitioners. Gates, in an extended interview with Braverman published in the latter's book *Coral Whisperers*, sums up the assisted evolution project thus: "we're accelerating natural processes. […] If we take the [corals] performing well now, can we lift their biology to perform even better? Can the best performers now become the better performers of the future?"[66] Gates describes coral conditioning as running individuals on "environmental treadmills" and as an

[63] Karen Filbee-Dexter and Anna Smajdor, "Ethics of Assisted Evolution in Marine Conservation," *Frontiers in Marine Science* 6 (30 January 2019): 20, 3.
[64] Filbee-Dexter and Smajdor, "Ethics of Assisted Evolution," 4.
[65] Isabelle Stengers, "God's Heart and the Stuff of Life," *Pli* 9 (2000): 86–118, 93.
[66] Gates, cited in Irus Braverman, *Coral Whisperers: Scientists on the Brink* (Berkeley: University of California Press, 2018), 236–7.

"engineering solution" to ocean warming.[67] In another interview given to Braverman, she says that the work of assisted evolution – a project which was, incidentally, funded by a nearly USD4-million-dollar grant from the Paul Allen Foundation, created by the co-founder of Microsoft – consists in:

> […] identifying the best of the best [this is the older meaning of "super corals"] and then bringing them into the lab to train them on environmental treadmills (intragenerational acclimatizations), providing the best nutrition (manipulations of the zooxanthellae and microbes), and finally selectively breeding them to genetically direct very high-performing offspring (transgenerational acclimatization).[68]

Considering Gates' choices when communicating about assisted evolution, it is perhaps unsurprising that she found herself cited as an exemplar of using "social design" to tackle environmental problems. In an essay adapted from her ominously neoliberally-titled book *The Intergalactic Design Guide: Harnessing the Creative Potential of Social Design*, Cheryl Heller describes the workshop in which the seeds for assisted evolution were sown. In 2012, Gates assembled an interdisciplinary team of conservation scientists and managers to answer the question "what should science be doing in the conservation of coral reefs?," an act described by Heller as one of "collaboration and net-worked cocreation" in which "[g]aining acceptance and active participation to put [Gates's] discoveries to work requires the skills and principles of social design. Gates imagines, and is building, a collaboration among diverse stakeholders, a supernetwork with the capacity to act on what she is learning."[69] Social design is an approach aiming to use design to approach and solve social problems, and its managerial and reductive language seems particularly suited to capturing the engineering potential of assisted evolution.[70]

Regardless of whether Gates would have subscribed to this description of her research, media coverage of assisted evolution has certainly latched on to the engineering aspect of the project, breathlessly reporting that marine scientists are breeding "super

[67] Gates in Braverman, *Coral Whisperers*, 237.

[68] Gates in Braverman, *Coral Whisperers*, 219. On the funding of the project, see "Paul G. Allen Supports Coral Reef Research to Reverse Rapid Decline," 4 August 2015, https://pgafamilyfoundation.org/Press-Room/2015/Coral-Reef-Research-to-Reverse-Rapid-Decline.aspx.

[69] Cheryl Heller, "How Ruth Gates Used Social Design to Protect the Coral Reefs," *Greenbiz*, 8 December 2018, https://www.greenbiz.com/article/how-ruth-gates-used-social-design-protect-coral-reefs.

[70] See Cinnamon L. Janzer and Lauren S. Weinstein, "Social Design and Neocolonialism," *Design and Culture* 6, no. 3 (1 November 2014): 327–43.

corals" to help reefs recover.[71] As a journalist writing about research at the Sea Simulator for *Science*'s news coverage put it:

> Van Oppen and others are re-engineering corals with techniques as old as the domestication of plants and as new as the latest gene-editing tools. And the researchers are adopting attitudes more common to free-wheeling Silicon Valley startups than the methodical world of conservation science. Just as tech entrepreneurs are urged to "fail fast, fail often," scientists are pushing to quickly test ideas and ditch the least promising ones in the hunt for results that can be moved from the lab to the ocean.[72]

This kind of sensationalist reporting is not necessarily to the taste of all the scientists working on assisted evolution, at least not to Van Oppen's. As she tells me during an interview, the term "super coral" is one she would rather not have applied to her lab's research, in contrast to Gates' willingness to use the term in her interviews with Braverman.[73] It nevertheless highlights one of the aspects which sets this case study apart from the two others I have previously examined: its acknowledged production of biological novelty.

But even as they engineer and design novel artefacts, the researchers involved in assisted migration and crop wild relatives conservation projects are engaged in a constant rhetorical process of "strategic naturalisation," a term I borrow from Charis Thompson's work on assisted reproductive technologies.[74] In the case of transformative conservation proposals, this naturalisation is conducted, as we have seen, through the foregrounding of "natural" and often supposedly immemorial forms of nonhuman movement (in assisted migration) or reproductive interactions (in crop wild relative conservation), with the effect of minimising the novelty of human intervention in these processes. While the occurrence of coral hybridisation in the field has been an important driver in coral science and in the development of recent conservation proposals, the artificiality of crossing *Acropora* species in the laboratory is more difficult to downplay given the discrepancies between their spawning times, and the highly regimented apparatus of technologies and

[71] The term has been used in news articles such as Damian Carrington, "New Lab-Bred Super Corals Could Help Avert Global Reef Wipeout," *The Guardian*, 23 December 2017; Angela Heathcote, "What Exactly Are Super-Corals?," *Australian Geographic*, 28 July 2018; and Priya Shukla, "Could These 'Super Corals' Withstand Climate Change?," *Forbes*, 25 March 2019.

[72] Cornwall, "Researchers Embrace a Radical Idea."

[73] Madeleine Van Oppen, interview by author, September 28, 2020.

[74] Charis Thompson, *Making Parents: The Ontological Choreography of Reproductive Technologies* (Cambridge, Massachusetts: MIT Press, 2005), 13.

practices necessary for bringing together gametes that might not easily meet in the ocean. This is particularly obvious when it comes to the differences between inter- and intraspecies breeding at the Sea Simulator. Van Oppen reminds me that "even though what we do in the lab is the same, the actual thinking behind it is slightly different": breeding corals from the same species for relative heat tolerance, where parents are selected from populations that have acclimatised or adapted to different climatic conditions, is very different from the negotiation with uncertainty that is inter-species breeding.[75] As the 2018 study detailing the year-long monitoring of *Acropora* hybrids states, "our purpose was to increase genetic diversity (and thus adaptive potential) via hybridization, and not to conduct targeted breeding with species of known relative bleaching tolerance."[76] Interspecific coral hybridisation does not select brood stock for already observed heat tolerance in the field, but rather operates by creating new genetic combinations, only some of which might turn out to be beneficial in changing ocean conditions. As such, hybridisation is premised on scientists' willingness to create unexpectedly novel forms of life, and to tend to them.

4. Entanglement and Withdrawal

As a space in which novel species are being produced and raised, and which is at least in part acknowledged to be a site of technological innovation, the Sea Simulator seems to be trafficking in forms of reification. As Van Oppen tells me during an interview, one of the goals of assisted evolution is to conserve at least part of the genome in more resilient bodies, "even if it's in the form of a hybrid"; and while she acknowledges that this is not an ideal or even sufficient conservation practice, she points out that it is better than the alternative of losing species entirely.[77] Seen from this angle, breeding coral hybrids would mean transforming coral bodies into mere vessels for genetic information, and therefore transforming a complex set of heterogeneous relations into a fixed thing that is the source of its own value.[78]

This potential for reification also ties into the colonial underpinnings of conservation biology and marine science. This particular form of speculative

[75] Madeleine van Oppen, interview with author, September 28, 2020.
[76] Chan et al., "Interspecific Hybridization," 3.
[77] Madeleine Van Oppen, interview by author, September 28, 2020.
[78] See Haraway, *Modest Witness*, 142-144.

conservation, and the right it gives itself to animate nonhuman bodies, species and becomings, is never free from the shadow of violence. The first identifiable danger is tied to the immobilising tendencies of conservation biology I mentioned before, which creates what Zoe Todd, drawing on Kim TallBear's work, calls artefacts, "things that no longer have immediate temporal agency – they are merely echoes of past worlds. In following TallBear's thinking, in western ontologies, artifacts are things (no longer a 'who') whose kinship has been severed: their people can no longer speak for or with them."[79] The spatial occupation of colonial expansion also goes hand in hand with a form of colonisation of the future; late capitalism is a formidable machine for reaching down into planetary pasts and using the archived remains of former times archived, such as the Carboniferous fossils which fuelled the industrial revolution, to accelerate the present and foreclose the future. As Zoe Todd points out in an essay about the power structures embedded in euro-western time and settler colonialism:

> Through the logics of its own science, white supremacy seeks to categorize humans in such a way to stretch its spindly white fingers back through the mammals, the dinosaurs, the marine creatures, the stromatolites, the nucleated-cells, the archeans, the prokaryotes, the very carbon and oxygen and hydrogen and nitrogen and atoms and electrons and quirks and quarks and energy that comprise this existence – they try to stretch that spindly finger back to the very beginning of *being* here on this planet, in the forms we understand being to take.[…] Artifacts are products of a specific and singular march of euro-western time, a march that drills down deep through the current epoch […] all the way back to the first geologic eon, the Hadean.[80]

Todd makes a compelling case here for analysing the specifically temporal processes of white supremacy, and the ways in which they empty out racialised bodies, conquered land, nonhuman life or nonlife by classifying and artefactualising them. Capitalism, and the imperialist and racist pillars it rests upon, enacts a reduction of worlds that touches every conceivable spatial, temporal and relational dimension. The toxicity of this use of Earth's past to colonise its future is physical as well as relational: the foreclosed, occupied future time-scape prepared by this extractivism makes relationships between agents so poisonous as to become impossible, halting flows of interaction and animacy that are part of time-scaping work. The natural sciences, developed and expanded in the crucible of

[79] Zoe Todd, "On Time," *Urbane Adventurer: Amiskwacî* (blog), 7 November 2018, https://zoestodd.com/2018/11/07/on-time/.
[80] Zoe Todd, "On Time."

colonialism, have always been a part of this process. Conservation biology is hardly immune from such artefactualisation of its material (be it species, bodies, places, ecosystems, which can all be transformed into objects to be worked upon), and it is important to note that the coral scientists of the AIMS have only recently started to work with Aboriginal bearers of traditional knowledge, for instance when it comes to selectively breeding *Acropora* corals from the Great Barrier Reef.[81]

But this critique of assisted evolution may be nuanced slightly, as it risks overlooking the material conditions of experimenting with and caring for hybrid corals in a laboratory. Laboratories, if we follow Haraway's analysis of technoscientific practices, are not only spaces of reduction; they are also places where technoscientific bodies are materially and semiotically produced as multiple, interacting, worlding entities, "forcing a revaluation of what counts as nature and artifact, of what histories are to be inhibited, by whom, and for whom."[82] This goes for assisted evolution laboratories too, and there are crucial elements of the concrete, embodied set of practices sustaining assisted evolution that resist the reifying tendencies of contemporary marine science. The reductive and selective practices of coral assisted evolution take place in a peculiar context of multiple influences and porous technological apparatuses. The constant oscillation between conductivity and separation, so peculiar to laboratories hosting aquatic species, permeates the conclusion of Hayward's article on cup corals. Corals, a "composition of faculties," are being regimented for experimental purposes, separated from their conspecifics for spawning, rinsed and purified and monitored.[83] But in return they "adjust to their environment: they feed differently in the nontidal zone of the laboratory; they respond to the segregation of sexes; their bodies strive varyingly in artificial darkness-lightness."[84] This oscillation is an important characteristic of laboratory work with corals, in which the negotiation of mutual influence must take into account the unique permeability of coral bodies to the medium in which they are grown. This is why the counterargument I offer here to framing assisted evolution as reification

[81] One of the PhD candidates supervised by Van Oppen was involved in one of the first field trials of the AIMS that engaged with Traditional Owners. The information booklet she wrote to communicate with Traditional Owners on Magnetic Island was circulated in 2020 (anonymous informant, interview by author, October 2, 2020).
[82] Haraway, *Modest Witness*, 119.
[83] Hayward, "FINGERYEYES," 584.
[84] Hayward, "FINGERYEYES," 593.

through design hinges less on entanglement than on the practice of a very specific kind of separation.

The Sea Simulator is, in fact, supposed to be merely a transitory space for hybridised corals. When I ask Van Oppen whether the hybrids bred in the first experiment are still alive at the Sea Simulator, and what their life cycle is at the laboratory, she reminds me that her team is breeding corals for one generation only. One reason for this is the cost of nurturing corals for several years and over several generations in a costly laboratory setup, but the other is that "we'd probably end up with corals – I should say, that might be domesticated and won't survive very well in the wild."[85] Of course, one generation in coral terms means that they will remain at the AIMS for several years, during which they will be enrolled in many other research projects; as Chan et al. state in the 2018 study, "[s]urviving hybrids and purebreds at the end of the experiment were transplanted to long-term grow-out tank for rearing with the aim to allow future assessment of their reproductive and backcrossing potential when they reach sexual maturity at ∼4 years of age."[86] Testing for this backcrossing potential is a crucial element in assisted evolution, as we will see later, but it is important to note that it does not imply the establishment of a large-scale captive breeding project for restoration.

Where Carrie Friese has asked how wild animal cloning projects make zoos into parents, Lorimer how conservation is increasingly contending with hybrid spaces and entangled actors, and Chrulew how zoo biology and reintroduction biology struggle with the acquired dependency of their subjects, one might also ask how in assisted evolution scientists are doing what they can *not* to step into a parentally entangled role.[87] The genetic effects of captivity have been documented extensively in endangered species bred for conservation purposes.[88] Corals, which are superlatively susceptible to water as an environing medium which constitutes their bodies, provides them with their symbionts and microbiomes and has the ability to induce rapid and inheritable epigenetic acclimatisation, are difficult laboratory subjects – too physically porous and too amenable to ex situ conditions not to "domesticate" rapidly. Observed laboratory effects on corals include the structure of their gametes and the composition of their bacterial communities,

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[85] Madeleine Van Oppen, interview by author, September 28, 2020.
[86] Chan et al, "Interspecific Hybridization," 3.
[87] Friese, "Cloning in the Zoo"; Lorimer, *Wildlife in the Anthropocene*; Chrulew, "Saving the Golden Lion Tamarin."
[88] See for instance Richard Frankham, "Stress and Adaptation in Conservation Genetics," *Journal of Evolutionary Biology* 18, no. 4 (1 July 2005): 750–55.

and one study recommending the sexual propagation of corals as a means to creating "bespoke" populations also states that collecting varied *Symbiodinium* strains from the wild is important in order to avoid the standardisation of lab-grown bacteria.[89] Laboratories and aquaria, and the emerging experimental space of transformative coral conservation in general, do not seem able to function either as a space of scientific purification or a viable backup for an endangered nature "out there," or as a site for producing entirely controlled, predictable and reified laboratory objects.

In *Coral Whisperers*, Braverman makes and immediately contradicts an argument concerning the erosion of the lab-field distinctions in marine science. She reads the genomic turn in coral science and conservation, and the rise of assisted evolution, as evidence that "the field (often interchangeable with the "wild") is becoming a gigantic lab, and the lab is becoming a refuge for the field." She immediately mentions that this has prompted a number of coral scientists to cling even more to the distinctions between laboratory and field work, citing an interview with an ecologist violently opposed to the "reductionist biologists" campaigning to do away with ecology and biogeography.[90] What Braverman does not mention, however, is that the scientists ranged on the side of laboratory science also seem invested in maintaining some form of distinction between what can be produced in experimental tanks and what will have to happen out on the reef, and that their work does not aim to transform corals into being completely dependent on the human mastery that created them. In the second half of this chapter, I propose to further investigate what happens when neither artefactualisation nor entanglement are taken to be self-evident, and when one of the operations of the laboratory is separation rather than inclusion – which I take to be very different from reduction to genes, traits, or functions.

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[89] F. Joseph Pollock et al., 'Coral Larvae for Restoration and Research: A Large-Scale Method for Rearing Acropora Millepora Larvae, Inducing Settlement, and Establishing Symbiosis', *PeerJ* 5 (6 September 2017): e3732–e3732, 15. On the effects of captivity on corals, see for instance Chiahsin Lin et al., "The Effects of Aquarium Culture on Coral Oocyte Ultrastructure," *Scientific Reports* 8, no. 1 (11 October 2018): 15159 and Pierre E. Galand et al., "The Effect of Captivity on the Dynamics of Active Bacterial Communities Differs Between Two Deep-Sea Coral Species," *Frontiers in Microbiology* 9 (2018): 2565.

[90] Braverman, *Coral Whisperers*, 228.

III. Generative Laboratories

This brings me back to the "worlds crafted through and for specific practices of intervening into particular ways of life"[91] that are being mapped out and modelled through the selective and regimented use of *Acropora* species at the AIMS. Here again, Haraway's distinction between types of maps is relevant; as she emphasises, maps and models can but do not have to be reductive or "nontroping," that is forgetful of the many transactions and interactions that are abstracted in the making of the map. She notes that geographical maps, for instance, can be the "embodiments of multifaceted historical practices among specific humans and nonhumans."[92] Nonfetishised maps and models are made to be inhabited and they map struggles, complexity and non-innocent practices rather than attempting to present abstract representations of places or bodies.

Just as Elizabeth Hennessy's critical geography of conservation genetics complicates the now well-established critiques of molecular conservation approaches by showing that it generates new possibilities for defining spaces and genealogies, and that in so doing it both reinforces and complicates notions of purity and pristine nature, I argue that the controlled and reductive space of the assisted evolution laboratory is intensely generative because of the forms of attention and withdrawal it allows. Corals, as ontologically and reproductively indeterminate entities, are being shepherded into a variety of abilities and evolutionary pathways rather than reduced to a single reproductive behaviour whose variables are easier to know and to control in laboratory conditions.

1. Coral Attributes

In fact, one of the most recent transmutations of coral epistemologies has more to do with what coral communities do as a whole than with identifying commodifiable genes or climate auguries. While corals have become more transparent to genomic technologies, they have also undergone a simultaneous transmutation that makes them thicker, teeming with a variety of processes still barely understood by marine scientists and often

[91] Haraway, *Modest Witness*, 135.
[92] Haraway, *Modest Witness*, 135.

difficult to isolate for observation. Now it is the severe marine heatwaves of the past decade and their destructive effects on coral reefs that have become a major driver in contemporary research on corals; scientific interest in the effects of heat stress on coral bleaching was triggered by the El Niño Southern Oscillation (ENSO) incident of 1998, the first mass bleaching event recorded by the National Oceanic and Atmospheric Administration (US). Combined with accumulated observations of ENSO events conducted during the two preceding decades, it provided conclusive evidence that climate change impacted marine ecosystems, and that the consequences of thermal shifts and bleaching events were much more dire than previously believed.[93]

Marine heat waves are perhaps one of the clearest examples of observable environmental and physiological disarticulation, as their cascading effects on coral physiology are more immediately obvious than in other organisms dependent on collaboration with a microbiome. Corals, or more accurately coral colonies, are sessile animals composed of up to millions of genetically identical polyps, small sac-like structures with a mouth and tentacles used for catching plankton and secreting, in the case of stony coral, a calcium carbonate skeleton. The corals Van Oppen and her colleagues are training their attention on belong to the category of zooxanthellate corals, meaning that they are colonised by single-celled dinoflagellates of the genus *Symbiodiniaceae* living in their inner gastrovascular membrane and acting as a mutualistic endosymbiont. The danger posed for coral colonies by increasingly frequent and severe marine heat waves consists in a breakdown of the relationship between the coral host and their symbiotic algae partners, which manifests as mass bleaching events.[94]

Triggered by temperature increases as small as one degree Celsius (as well as a host of other adverse conditions, including but not limited to changes in solar radiation or salinity, the presence of silts, toxicants or abnormally high concentrations of zooplankton leading to oxygen starvation), the polyps either expel or destroy their algal symbionts, a process still only partly understood but believed to result from the accumulation of reactive oxygen species in heat- and light-stressed symbionts and

[93] See Maha J. Cziesielski, Sebastian Schmidt-Roach, and Manuel Aranda, "The Past, Present, and Future of Coral Heat Stress Studies," *Ecology and Evolution* 9, no. 17 (September 2019): 10055–66.
[94] See T. P. Hughes et al., "Climate Change, Human Impacts, and the Resilience of Coral Reefs," *Science (New York, N.Y.)* 301, no. 5635 (15 August 2003): 929–33.

subsequent damage to their membranes and to the host tissue.[95] This cellular cascade triggers an immune reaction from the host, disrupting the usually "controlled infection" by zooxanthellae and their ability to modulate their host's immune responses and resulting in the expelling, in situ degradation or destruction, or apoptosis of the algae.[96] This is a significant loss for coral hosts, as algal symbionts not only play a nutritional role for their coral hosts – providing their photosynthetic abilities, without which the polyps could not feed – but also ensure the effective calcification of these polyps and therefore the building of the vast coral skeleton that provides the basis of all modern reefs.[97] This bleaching process does not spell immediate death for the colony but leaves it significantly weakened unless it can take up new zooxanthellae again. While this can occur in seasonal bleaching events observed in some coral species, where corals lose part of their symbionts for a few months every year, the persistence of adverse environmental conditions during mass bleaching events makes the renewal of this relationship impossible, and leads to the death by starvation of the polyps, and the eventual decay and erosion of the hard coral skeletons that form the basis of reef structures.[98]

As a result, heat wave research has had to contend with the corals as a multiplicity of imbricated but separable beings and processes, encountering corals as what Helmreich calls "a model for distributed subjectivities and agencies."[99] Studies in the 1990s highlighted the importance of algal symbionts in the thermotolerance of corals, and investigated a variety of processes by which Symbiodiniaceae respond to changes in heat and light and assist their coral hosts in adjusting to them. The use of protein biomarkers – a set of measurable indicators of biological states – had been an important element in discovering that coral hosts experienced oxydative stress as a result of damage to their symbionts, but was supplanted "when new technological advancement enabled expression analysis of various mRNA transcripts, simultaneously."[100] Transcriptomics, for

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[95] See Michael P. Lesser, "Coral Bleaching: Causes and Mechanisms," in *Coral Reefs: An Ecosystem in Transition*, ed. Zvy Dubinsky and Noga Stambler (Dordrecht: Springer Netherlands, 2011), 405–19.

[96] See V. M. Weis, "Cellular Mechanisms of Cnidarian Bleaching: Stress Causes the Collapse of Symbiosis," *Journal of Experimental Biology* 211, no. 19 (1 October 2008): 3059–66, 3062.

[97] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10055.

[98] See Orit Nir et al., "Seasonal Mesophotic Coral Bleaching of *Stylophora Pistillata* in the Northern Red Sea," *PloS One* 9, no. 1 (15 January 2014): e84968–e84968. The authors conclude with the intriguing possibility that this seasonal fluctuation could mean that "there may be an oscillation in the mesophotic coral-algae relationship from mutualistic relationship in the summer to parasitic in the winter." (7).

[99] Helmreich, "How Like a Reef," 54.

[100] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10057.

instance, have been used to identify common cellular response patterns and the genes associated with them, and to identify a "core cnidarian heat stress response."[101]

The need to understand how and why mass bleaching occurs has led researchers to investigate the role of the coral holobiont – "the totality of the coral symbiotic relations including, but not limited to, endosymbiotic zooxanthellae, bacteria, archaea, viruses, and fungi"[102] – in thermal stress responses. While this research has been fuelled by the growth of various "-omics" tools (genomics, transcriptomics and so forth), some marine scientists have called for caution, pointing out that "the targeted biological question should drive the use of these tools instead of embarking on a frenzy of large-scale sequencing" and that physiological validation of -omics results is a crucial element in furthering heat stress studies.[103] The atomisation of scientific methods pointed out by Cziesielski, Schmidt-Roach, and Aranda is accompanied by another disarticulation in coral heat stress science, in which "the study of Cnidarian host and Symbiodiniaceae temperature response are often pursued as separate fields."[104]

As Haraway – and after her Helmreich – notes, figures are never only metaphorical or rhetorical constructs. Corals and coral reefs emerge as representations but also as models, more specifically as an enlarged, easily legible model of the various processes that can or could intervene in evolution, adaptation, and acclimatisation to various environmental changes. As particularly fragile victims of climate change – sensitive to even small variations in temperature, and, in the case of mature colonies, tethered to their degraded environments by their sessility – corals are being increasingly assessed not only for their fragilities but also for the processes and attributes which allow for acclimatisation and survival. Having trained their attention on the precarious symbiotic equilibrium sustaining zooxanthellate coral colonies, researchers are currently learning to understand the various processes which can intervene in coral acclimatisation and evolution, and how they interact, and in doing so explode corals into a multiplicity of physiological attributes. As Van Oppen and her co-authors put it:

> Corals possess a range of attributes that promote evolvability, including (i) the common occurrence of asexual reproduction in addition to sexual reproduction –some corals brood larvae asexually and others reproduce

[101] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10058.
[102] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10060.
[103] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10060.
[104] Cziesielski, Schmidt-Roach, and Aranda, "Coral Heat Stress Studies," 10061.

> asexually through fragmentation or colony fission; (ii) a lack of segregation of the germ cell from the somatic cell line; (iii) the existence of symbiosis with a range of potentially fast-evolving microbes; and (iv) naturally occurring high levels of genetic diversity and the occurrence of interspecific hybridization in some taxa. […] Such characteristics provide not only greater scope for environmentally induced epigenetic changes but also somatic mutations to be passed on from one generation to the next compared with strictly sexually reproducing organisms […]. Therefore, corals possess a variety of characteristics that make them likely candidate organisms for assisted evolution initiatives.[105]

What is fostered in assisted evolution research is thus more complex than mere genetic reduction, and the controlled conditions of the laboratory have oriented attention toward a wealth of processes that are still surprising, only partially understood, and exceed straightforward projects of control. Assisted evolution, in fostering a range of coral traits and processes, relies on the subjectification rather than the reification of its experimental hybrids.

2. Polymodal Reproduction

Reproduction is one area in which this attention to the immense variety of coral processes has informed an important epistemological and experimental shift. The rich and complex polity sustaining coral bodies and reefs means that their reproductive status can fluctuate depending on which scientific or economic apparatus it is being fostered within. Coral reproduction is fluid, multiple, and murky enough to merit the Harawayan description of "replicative doings," a phrase perfectly formulated to encompass the variety of processes by which corals can multiply: polyps can do so vegetatively, which means that "reproduction" proper only represents one part of coral perpetuation strategies. The individual polyps of a coral colony can reproduce asexually by budding, through "a process of modular iteration," which ultimately builds the calcium carbonate skeletons that are characteristic of scleractinian corals;[106] but, as we have seen in Van Oppen's experiments on *Acropora* species, corals also reproduce sexually through broadcast spawning, the synchronised release of sperm and eggs over one or several

[105] Van Oppen et al., "Building Coral Reef Resilience."
[106] Jonathan A. Barton, Bette L. Willis, and Kate S. Hutson, "Coral Propagation: A Review of Techniques for Ornamental Trade and Reef Restoration," *Reviews in Aquaculture* 9, no. 3 (September 2017): 238–56, 238.

nights, usually around a full moon, and produce gametes that become coral larvae and drift until they find a spot to attach to and settle on in their turn.

Sexual reproduction was only discovered during the second phase of Helmreich's coral historiography, when the development of new visual and diving technologies enabled researchers to take a closer, immersive look at what these polyps were up to. It was only in the late 1970s that corals were discovered – by the marine science community, at least – to not be viviparous (that is, to brood viable offspring rather than broadcast gametes). Mass spawning was witnessed and described in 1984 by several James Cook University scientists, "invalidat[ing] the generalization that most corals have internally fertilized, brooded planula larvae."[107] Now the problem of coral sex, *pace* Helmreich, is still at the center – or has moved back to the center – of transformative coral conservation proposals. Coral species have long been treated almost exclusively according to their plant-like abilities when it comes to restoring them *en masse* in depleted sites, a practice facilitated by the ease with which corals fragment: natural disturbances often cause coral pieces to break off, and these fragments can reattach to a new substratum and bud into a new coral colony.[108] Coral's "modular habit, asexual and sexual reproductive mechanisms and minimal feeding requirements" have been singled out to explain the ease with which they can be maintained and propagated in captivity.[109] Asexual propagation is also a more cost-effective method than sexual propagation, which has been estimated to cost US$60 for a single 2.5 year coral, and has therefore been a favoured aquaculture technique for both ornamental trade and coral reef restoration until now.[110] In 2013, researchers at the AIMS and the University of the Philippines Marine Science Institute published the results of a long-term study that had seen the rearing circle closed – nursing corals in laboratories from eggs to mature individuals transplanted on the reef and monitored over three years after their settlement for survival and fertility – and concluded that "it is likely that the

[107] See Peter L. Harrison et al., "Mass Spawning in Tropical Reef Corals," *Science* 223, no. 4641 (16 March 1984): 1186–89.
[108] Barton, Willis, and Hutson, "Coral Propagation," 240.
[109] Barton, Willis, and Hutson, "Coral Propagation," 239.
[110] See J. R. Guest et al., "Closing the Circle: Is It Feasible to Rehabilitate Reefs with Sexually Propagated Corals?," *Coral Reefs* 33, no. 1 (1 March 2014): 45–55, and Ronald D. Villanueva, Maria Vanessa B. Baria, and Dexter W. dela Cruz, "Growth and Survivorship of Juvenile Corals Outplanted to Degraded Reef Areas in Bolinao-Anda Reef Complex, Philippines," *Marine Biology Research* 8, no. 9 (1 November 2012): 877–84.

high cost per coral using sexual propagation methods would constrain delivery of new corals to relatively small scales in many countries with coral reefs."[111]

As we have already seen, the sexual reproduction of corals has been discussed in the literature as a useful pathway to introducing novelty and tailoring coral strains to various potential research projects.[112] But assisted evolution is one of the rare areas of coral conservation in which this costly and time-consuming form of propagation has emerged as a crucial technology for enabling coral survival. According to Ruth Gates, "[t]here's very little attention to the most robust genotypes […] It's just: we fragment [i.e. perform asexual reproduction], like in plants. We go quickly, and we don't really pay attention to genetics."[113] But now that using local coral stock to restore reefs is a possibility coming increasingly undone by successive and overlapping marine heatwaves and mounting acidification of already inhospitable waters, new dimensions of the peculiar actants that corals are seem to become significant: not merely their being-animal, but the fact that they so flexibly combine modes of reproduction, and are therefore able to pass on various accidents of mutation and adaptation to their kin through multiple pathways. The problem of assisted evolution is becoming not merely to reintroduce corals from where they have been discouraged to grow, but to introduce significant and transmittable *differences* into endangered coral species. The question of assisted evolution, the matters of concern it addresses, if we are to speak in Stengerian terms, represents a profound rerouting of the networks in which certain species, certain traits or aspects, and certain capabilities become significant in conservation biology where they weren't before.[114]

This connects intriguingly to an emergent phenomenon in the field of "extreme" or "last-ditch" botany. Extreme botany is the conservation of plants so endangered that extant wild or captive populations only consist of a few individuals, or of recalcitrant plants whose seeds cannot easily be kept in seeds banks or which do not produce seeds at all. In 2016, several researchers working either in various botanic gardens or for the Chicago Zoological Society co-authored an essay in the *American Journal of Botany* titled "What to do when we can't bank on seeds: What botanic gardens can learn from the zoo community about conserving plants in living collections." One of the examples used in this

[111] Guest et al., "Closing the Circle," 45.
[112] See Pollock et al., "Coral Larvae for Restoration and Research."
[113] Quoted in Braverman, "Biopolarity," 37.
[114] On this topic, see also Despret, *What Would Animals Say*.

article is that of *Brighamia insignis,* a Hawai'ian succulent of which only one specimen is still alive in the wild after two hurricanes decimated the already fragile remaining populations, and which is being propagated from the plants grown in several botanic gardens in Hawai'i and elsewhere. While this has at least nominally prevented the extinction of *Brighamia insignis*, seed production has gone on to decrease significantly, prompting an investigation into the species' genetic robustness: it appears that the effects of inbreeding – the original seeds were collected from fifteen wild plants – are starting to severely affect its fertility:

> Currently, management efforts have focused on propagating individuals rather than on maintaining genetic diversity. This situation is particularly concerning because recent research showed that genetic diversity of *Brighamia insignis* is not equally distributed among ex situ collections […]. Unfortunately, there is no system in place to identify appropriate pollen donors, facilitate inter-institutional crosses, or plan for how seed produced should be distributed to improve the genetic and demographic prospects of this species globally.[115]

The solution for conserving *Brighamia* and other "exceptional plants" – which might make up to nine percent of the world's threatened species – is, according to the authors, to import zoo-biological techniques. Jeremie Fant, one of the authors of the paper, is quoted on the topic in a popular science article about extreme botany. "One thing botanic gardens haven't done, says Fant, is see plants as distinct individuals. 'Zoos manage their animals as individuals,' he says, 'but plants are usually maintained as a collection and rarely is any one individual perceived as a unique member of that species.'"[116] The authors of the original paper argue that genetic diversity and robustness can only be restored if plants are treated like the individual animals involved in the dense genealogical apparatus of studbooks and inter-zoo breeding plans. "As plants become rarer in the wild and as restoration efforts are scaled up, there will be greater congruence with methodologies employed in other disciplines."[117]

John Hartigan, in *Care of the Species*, uses a definition of conservation as artificial selection in order to trace the various forms of care that create maize landraces and

[115] Jeremie B. Fant et al., "What to Do When We Can't Bank on Seeds: What Botanic Gardens Can Learn from the Zoo Community about Conserving Plants in Living Collections," *American Journal of Botany* 103, no. 9 (1 September 2016): 1541–43, 1542.

[116] Janet Marinelli, "Extreme Botany: The Precarious Science of Endangered Rare Plants," *Yale Environment 360* (blog), 18 October 2018, https://e360.yale.edu/features/extreme-botany-the-precarious-science-of-saving-rare-endangered-plants.

[117] Fant et al., "What To Do", 1542.

attention to endangered species in botanic gardens. "Escalating efforts at conserving and cultivating biodiversity are extending such forms of care to species with little or no direct value for humans, blurring an important contrast with the domesticates we have transformed over millennia."[118] I find this an interesting approach to what seems to be happening in assisted evolution and last-ditch botany, since they might in fact be selecting for certain forms of plasticity or categorial translatability. This is particularly important to keep in mind because at first glance everything seems to be pointing toward a potential superiority, in conservationist terms, of treating plants like animals when it comes to the maintenance of their genetic diversity, or rather their evolvability, their ability to tie into futures by bequeathing ongoing plasticity to their descendants. However, the matter here is not one of shifting these endangered species into a more viable kingdom, or of granting them a higher biopolitical status in order to refine the management techniques necessary for their survival. I would rather argue that it is the very categorial unruliness or indecisiveness of these particular species that make them such good candidates for these proposals. Exceptional plants and hybridising coral species do not seem to be cast as particularly salvageable because they can act similarly to and be managed like animals in captivity; rather, they are so because they have the ability of participating in both these regimes, shuttling back and forth between modes of endangerment and modes of survival, developing new abilities or presenting new resistances when they are placed into new configurations of attention, management, care, and experimentation.

This renewed emphasis on sexual reproduction, and therefore on the animal-being of corals, could appear as a problematic reinforcement of existing hierarchies of nonhuman nature and of rigidly defined reproductive biopolitics. While plants do, of course, also reproduce sexually, there seems to be a semantic slide in coral conservation which equates the fragmentation of corals with their vegetal characteristics, and sexual reproduction with their animal being – or at least, animals *as they have been constructed* in ex situ institutions such as zoos, as traceable genealogies and known individuals. Here, "animal" does not necessarily name a superior degree of ontological or behavioural richness, but rather stands in for certain forms of traceable kinship, for emerging difference, recombination, and the mobilisation of inheritability. In short, what happens in the peculiar experimental space created at the AIMS, where entanglement is partially

[118] John Hartigan, *Care of the Species: Races of Corn and the Science of Plant Biodiversity* (Minneapolis: Minnesota University Press, 2017), xv.

curtailed by the active maintenance of boundaries, is the construction and fostering of newly understood ways of working and networking, of a coral labour that must be intervened in while also enabled to exist outside of the acclimatising conditions of the rearing tank.

IV. Kinship, Work, and Time

1. Coral Extinction

In order to understand what exactly assisted evolution is aiming to counteract, it is important to be precise about the definition of the concept of extinction in coral science. Here we must turn to one significant characteristic of coral evolutionary history, namely their specific mode of persistence through several mass extinction events. Joshua Schuster has examined the complexities of "[c]oral's charismatic life and charismatic death," highlighting how coral, in scientific accounts and popular imagination, has been shifting between resilience and fragility. Schuster notes that "coral's multiple vulnerabilities and perilous conditions have become now enmeshed with its previous characterizations of enchantment and strangeness," transmuting a previous paradigm of unimaginably old and robust reefs into one of fragile sessility, entirely exposed to increased environmental stressors.[119] The same oscillation marks coral palaeobiology, a field in which it has been noted that corals seem to be both vulnerable and resistant to mass extinction events. Marine scientists make an important distinction between extinction and coral reef disappearance; Ove Hoegh-Guldberg, for instance, emphasises that "coral reef extinction" is a phrase "generally used to describe the disappearance of coral reefs as an ecosystem, which is very distinct from the extinction of a particular coral reef species."[120] This is an important element in the evolutionary history of corals, especially that of scleractinian corals, the reef-builders we know today and to which the branching *Acropora* belong. While it "has remained an unsolved problem in paleontology,"[121] their emergence has been dated back at least to the Middle Triassic. Their evolutionary success has been linked to the advent of their associations with symbionts in the Late Triassic, which means that reef-building zooxanthellate corals have already weathered several periods of severe environmental perturbation.[122] The most

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[119] Joshua Schuster, "Coral Cultures in the Anthropocene," *Cultural Studies Review* 25, no. 1 (25 September 2019): 85–102, 87.

[120] Ove Hoegh-Guldberg, "Coral Reefs, Climate Change, and Mass Extinction," in *Saving a Million Species*, ed. Lee Hannah (Washington, Covelo, London: Island Press, 2012), 261.

[121] George D. Stanley, "The Evolution of Modern Corals and Their Early History," *Earth-Science Reviews* 60, no. 3 (1 February 2003): 195–225, 195.

[122] On the advent of symbiotic associations in scleractinian corals, see George D. Stanley Jr., "Early History of Scleractinian Corals and Its Geological Consequences," *Geology* 9, no. 11 (1 November 1981): 507–

notable among them are, of course, the Triassic-Jurassic and Cretaceous-Tertiary mass extinction events, but they have also survived other, less universally destructive catastrophes and demographic fluctuations.[123]

Scleractinian corals certainly survive massive environmental disturbances. But, significantly, they do so at the cost of the reefs they build and the symbioses they can enter into. A recent comparative study of coral evolution, for instance, states that:

> deep-sea (>100 m), non-symbiotic and solitary corals or with small colonies, among other studied traits, are associated with the survival during the Cretaceous–Paleogene mass extinction event and will have more chances of survival in a near-future. On the other hand, every cycle of reef collapse in the past involved a different degree of loss of symbiotic and colonial forms with posterior recovery and diversification of the survivor lineages, but also with new origins of symbiotic and colonial forms from solitary and az-coral ancestors […].[124]

What this means is that corals have historically retreated into individuality for long stretches of time after extinction events, recovering alone, in deeper and cooler depths, before coming together in reefs again after millions of years of so-called "reef gaps."[125] These evolutionary fluctuations provide a good illustration of what van Dooren calls the collective, collaborative work of "countless generations of all kinds holding themselves and each other in the world."[126] They have also recently taken on the aspect of a rather sinister warning, as a study published in 2020 has found that corals worldwide might be preparing for just such a catastrophe, and just such a recovery too: the authors note that current trends in coral species show "distinctive similarities between coral traits that survived the K-T mass extinction event and those that are least threatened in the current extinction event," an observation which, according to them, "provides alarming evidence that reef communities are currently in the process of transitioning into disaster communities, akin to previous extinction events."[127]

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11. On the perturbations that have marked their evolutionary history, see Sara B. Pruss and David J. Bottjer, "The Reorganization of Reef Communities Following the End-Permian Mass Extinction," *Comptes Rendus Palevol* 4, no. 6 (1 September 2005): 553–68.

[123] See Stanley, "The Evolution of Modern Corals."

[124] Ana Navarro Campoy et al., "The Origin and Correlated Evolution of Symbiosis and Coloniality in Scleractinian Corals," *Frontiers in Marine Science* 7 (19 June 2020): 461, 7.

[125] See Pruss and Bottjer, "The Reorganization of Reef Communities."

[126] Van Dooren, *Flight Ways*, 43.

[127] Gal Dishon et al., "Evolutionary Traits That Enable Scleractinian Corals to Survive Mass Extinction Events," *Scientific Reports* 10, no. 1 (3 March 2020): 3903.

Corals thus display the double characteristic of being potentially prepared for survival in the case of another mass extinction event, but of being so at the cost of their unique collaborative, social, architectural, multispecies form. Breeding more resistant corals is not only about individual survival, but about the form this survival might or might not take, the prolonging of interspecies collaborations which are more tenuous than the persistence of individual coral species themselves. According to the article coining the term "dead clade walking" – a term used for clades that survive mass extinction events only to remain marginal or decline afterwards – "[s]imply surviving a mass extinction is no guarantee of success in the aftermath."[128] *Recovery* is very different from *survival*, and the available literature suggests that the work of assisted evolution is focused on the former rather than the latter. It necessarily takes place in what van Dooren calls the "edges of extinction," a concept he proposes in order to rework our dominant understanding of how species die. The focus on last individuals, whether as emotional spectacle or in conservation efforts, is something he critiques as presenting "a species as somehow 'ongoing' because one individual continues to draw breath in a zoo, while the entangled relations that in a nontrivial sense are this particular life form and its form of life, have long ago become frayed and disconnected."[129] Focusing on extending the survival of an individual, whether hybrid or not, is precisely what assisted evolution cannot afford to do, either ecologically or financially; it can only hope to put these individuals to work, and to do so in a way that is viable outside of the captivity in which they were conceived.

In putting evolution to the test in laboratory settings, tweaking not only bodies and genomes but the mechanisms of *evolvability* itself, assisted evolution thus engages in an active re-definition of what extinction is, or what goes extinct when coral reefs unravel. Here, I take up a philosophical proposal formulated by Joshua Schuster in his investigation of how the issue of extinction complicates any attempt at structuring a robust philosophy of life:

> I do not take it for granted that we know what the philosophical, psychological, literary, and biological effects of extinctions [are], or even to what extent extinction can be cognized at all. Circumstances of contingency and finitude suffuse processes of natural selection at work in the generation and collapse

[128] D. Jablonski, "Survival without Recovery after Mass Extinctions," *Proceedings of the National Academy of Sciences* 99, no. 12 (11 June 2002): 8139–44.
[129] Van Dooren, *Flight Ways*, 11.

> of life, and it is an open question how these same circumstances factor into any philosophical conceptualization of life […]. [H]ow then should one construct a philosophical thought on life within its own limits and parameters, and especially within its own finitudes?[130]

Schuster points out the necessity for incorporating a richer and more nuanced understanding of what extinction is and does into any philosophical definition of life – an understanding that takes into account the ways in which extinction both undermines life and makes it possible through ongoing processes of speciation, and the precariousness and changes in species form inherent to life, without diminishing the importance of discrete species or the ecological and existential weight of their loss. I situate my own enquiry within a similar set of concerns; a meaningful and nuanced analysis of counter-extinction practices must also work toward questioning and redefining the assumptions about extinction that underpin them. As Schuster puts it, "futural indifference does not supersede a being's stake in its affairs, but is the co-constitutive condition of care for beings that persist, inhabiting the double bind of difference/indifference. Without loss and extinction, as in philosophies of endless becoming, there is no ecology; but too much loss and extinction, there is also no ecology."[131] Critical analyses of conservation might enrich such a philosophical project significantly, as it is precisely the field in which the questions of what extinction is, what its place ought to be in the management of life, and to what extent it must be accepted or worked with, are currently being grappled with.

2. Time and Animacy

As we have seen, the temporality of assisted evolution seems not based on the idea that destruction can or should be skipped; its paradigm is not that of the ark, nor does it take place in the "zone of the incomplete," which Rose critiques as the messianic dream of technological mastery over biological processes.[132] Asking how conservation projects enact, counteract, recreate or invent time-scapes, how they are involved in landscaping time and not only space, is to ask about animacy. I use the term here in a sense inspired by Mel Y. Chen's scholarship but only adjacent to it, as my scope here is much more restricted and deals mainly with the ways in which endangered species can avoid the fate

[130] Joshua Schuster, "Life After Extinction," *Parrhesia* 27 (2017): 88–115, 89.
[131] Schuster, "Life after Extinction," 110.
[132] See Rose, "Reflections on the Zone of the Incomplete."

of (seemingly) de-animated laboratory objects in conservation biology. I do, however, make a slightly unfaithful use of the idea that "we can then ask not 'who is alive, or dead,' but 'what is animate, or inanimate, or less animate' […] For animacy is a category mediated not by whether you are a couch, a piece of lead, a human child, or an animal but by how you interpret the thing of concern and how dynamic you wish it to be."[133] The question of how dynamic researchers wish the species they are dealing with to be, and how their shifting conservationist assemblages make them more or less animated, is a crucial one.

Environmental scholarship has been turning for some time now toward an exploration of the temporalities of extinction and of the way species end. The overarching importance of time and its production, the collaborative tending to its textures and rhythms, has been emphasised by scholars such as Deborah Bird Rose, notably in her characterisation of extinction as a double death – the death of death itself, of the time and opportunity to perform death correctly and to weave it into cycles of material and semiotic transmission. "In a few short centuries, the human species has begun unmaking the balance on earth between life and death, enabling death to expand and expand, tilting life toward a catastrophe that is difficult to imagine, difficult to think, and yet morally imperative to consider," she writes in *Wild Dog Dreaming*. "Along with the loss of existing life forms, there is a further, equally critical, loss of new life forms. This means that in our day species being lost are not being replaced. We are seeing the death of evolution in many large classes of life forms."[134]

Michelle Bastian similarly argues that the death of a species can be the result of an increased vulnerability predicated on lethally disrupted rhythms: the leatherback turtles she writes about are dying not *only* because of fishing, not *only* because of climate change, not *only* because of plastic in the oceans, but because all these processes are producing their own disjointed rhythms, and their overlap creates a lethal friction for creatures dependent on their earlier synchronicity or asynchronicity.[135] Bastian points out that conservation work, in this context, can also mean the necessity of disentangling

[133] Mel Y. Chen, 'Toxic Animacies, Inanimate Affections," *GLQ: A Journal of Lesbian and Gay Studies* 17, no. 2–3 (1 January 2011): 265–86, 280.
[134] Deborah Bird Rose, *Wild Dog Dreaming: Love and Extinction* (Charlottesville: University of Virginia Press, 2011), 61. See also Deborah Rose, 'Multispecies Knots of Ethical Time', *Environmental Philosophy* 9 (1 January 2012): 127–40.
[135] Michelle Bastian, "Encountering Leatherbacks in Multi-Species Knots of Time," in *Extinction Studies: Stories of Time, Death and Generations.*, ed. Deborah Bird Rose, Matthew Chrulew, and Thom Van Dooren (New York: Columbia University Press, 2017).

temporalities, of severing rhythms dangerously brought together – as such, it appears as a practice of temporal re- or unweaving as much as one of spatial re-stitching. We see here that *time* is of course always of the essence when dealing with or speaking of extinction and counter-extinction; but *temporality*, the quality and texture of the relationships a species, a group of researchers, an ecosystem can or cannot have with time, is just as crucial.

The question then becomes: what and who is being animated, and as what? Given the crucial distinction made by certain coral scientists between the extinction of a coral species and the extinction of a coral reef – of the result, in other words, of the collaborative work of centuries and generations – it is not the vitality or vibrancy of coral bodies and matter in and of themselves, but rather the potential for actively constructing relationships and fostering liveable environments. In other words, corals are being animated as labouring, kin-making creatures, a practice which contains the potential to rethink how we characterise the occurrence of processes by which a polity of species makes its way across the terrain of extinction.

3. Kinship and Labour

In fact, one could argue that assisted evolution recasts nonhuman kinship *as* work, as the possibility of generating and extending agency through collaboration. This is particularly salient in the emergence of coral interspecific hybridisation, not only as an experimental project but also as a phenomenon of epistemological importance both in the field and in the laboratory. This process has been studied in the field, as a harbinger of climate change and a potential guide to coral acclimatisation; historically, in attempts to understand coral biology and to challenge claims about the importance of climate change in coral evolution; and finally, it has been reproduced in laboratory environments as a test of field hypotheses (and, of course, as a novel engineering tool in the case assisted evolution).[136]

[136] See for instance William F. Precht et al., "Fossil Acropora Prolifera (Lamarck, 1816) Reveals Coral Hybridization Is Not Only a Recent Phenomenon," *Proceedings of the Biological Society of Washington* 132, no. 1 (1 April 2019): 40–55; Bette L. Willis et al., "The Role of Hybridization in the Evolution of Reef Corals," *Annual Review of Ecology, Evolution, and Systematics* 37, no. 1 (7 November 2006): 489–517.

Occurrence in the field, however, does not always mean that hybridisation is unproblematic. The case of the *Acropora prolifera* shows very clearly that the problem of hybridisation in corals is far from being settled among scientists and conservationists.[137] This hybrid, which is found in the Caribbean Sea, the Bahamas and Florida, has been at the centre of a debate for a few years now, in which its detractors – who would deny it the status of a full species and therefore any kind of conservationist protection – are pitted against those who argue that its potential fertility makes it a valid agent in coral evolutionary history.[138] The problem with coral hybrids is that they can go on reproducing asexually and therefore constitute effectively "immortal" individuals, and that the scientists opposed to their inclusion in conservation projects still mobilise normative reproductive definitions in order to dismiss the *prolifera* as a species with no evolutionary agency, no ability to form evolutionary relationships, and therefore no persistence in evolutionary time.[139] Van Oppen, significantly, has ranged herself on the pro-hybrid side of the debate, arguing with several co-authors that it is a distinct species with "semipermeable boundaries," and that the analysis of its ribosomal DNA suggest that it "backcrosses with the parental species at low frequency."[140]

Unlike the ontological issue created by the problematic hybrid Florida panthers we encountered earlier, the question of coral hybridisation is being evaluated in terms of efficacy, of whether the beings it produces can or cannot continue involving themselves with other corals and thus weave themselves into a future that stretches beyond them. Beyond the issue of *Acropora prolifera* individuals in the field, this is the next crucial question that researchers working on assisted evolution are going to face once the first-generation hybrids reach sexual maturity. The work of the assisted evolution project at the AIMS is, in fact, far from finished, with the next hurdle being to ascertain whether and how these hybrids can backcross with their parents.[141]

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[137] See Naoko Isomura, Kenji Iwao, and Hironobu Fukami, "Possible Natural Hybridization of Two Morphologically Distinct Species of Acropora (Cnidaria, Scleractinia) in the Pacific: Fertilization and Larval Survival Rates," *PLOS ONE* 8, no. 2 (14 February 2013): e56701.

[138] For an overview of the debate see Braverman, *Coral Whisperers*, 211.

[139] On the potential "immortality" of *Acropora prolifera*, see Steven V. Vollmer and Stephen R. Palumbi, "Hybridization and the Evolution of Reef Coral Diversity," *Science (New York, N.Y.)* 296, no. 5575 (14 June 2002): 2023–25.

[140] Madeleine J. H. Van Oppen et al., "Examination of Species Boundaries in the Acropora Cervicornis Group (Scleractinia, Cnidaria) Using Nuclear DNA Sequence Analyses," *Molecular Ecology* 9, no. 9 (1 September 2000): 1363–73, 1871.

[141] See for instance Chan et al., "Interspecific Hybridization."

In this, assisted evolution is enacting, or at least laying the potential groundwork for, something that looks very much like the opposite of the strategic naturalisations at work in assisted migration and crop wild relative conservation. In casting coral labour and collaboration as a historicised object of ecological study and the variously configurable focus of experimental research, it arguably denaturalises *all* forms of reproductive and metabolic labour. This reading is partly based on Sophie Lewis' work on reproductive technologies and surrogacy, and in particular on her theorisation of what she calls "uterine geography." Lewis argues that paying attention to the distributed sites, technologies and bodies doing gestational work, including the many existing forms of surrogate gestation, draws attention to the "contingent and artificial but also *conscious* and fragile character of kinship, identity and relatedness," revealing not only surrogacy but any act of gestational and reproductive labour as fundamentally non-natural.[142] As spaces of surrogacy, the laboratories where assisted evolution is fostered and researched produce a wealth of knowledge and capabilities that historicise and contextualise what corals are thought to be doing "naturally" in the field, and reveals the complex structure of reefs as the precarious result of labour, lineages and traditions that must be actively sustained.

I propose to read the deferral of parenthood glimpsed in Van Oppen's statement about the future of her first-generation hybrids as a form of strategic disentanglement, which can be read through the lens of what Eva Haifa Giraud calls an "ethics of exclusion, which pays attention to the entities, practices, and ways of being that are *foreclosed* when other entangled realities are materialized."[143] This exclusion can be marginalising or oppressing, but Giraud also notes that in certain instances it can be a necessary political move that "particular forms of exclusion, refusal, and opposition play a productive and creative, rather than wholly negative, role."[144] In assisted evolution, foreclosing the possibility of corals acclimatising too well to laboratory conditions is what may allow them, in the future, to take back to the field what they have acquired in the laboratory; a goal not fully subordinated either to the demands of design and mastery or to the dream of allowing nonhuman agency to remain uninfluenced.

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142 See Sophie Lewis, "Cyborg Uterine Geography: Complicating 'Care' and Social Reproduction," *Dialogues in Human Geography* 8, no. 3 (November 2018): 300–316, 307.
143 Eva Haifa Giraud, *What Comes after Entanglement?: Activism, Anthropocentrism, and an Ethics of Exclusion* (Durham and London: Duke University Press, 2019), 2.
144 Giraud, *What Comes After Entanglement?*, 3.

4. Futures

Ultimately, I propose that viewing conservation practices as futural interventions into time-scapes is also one possible pathway to thinking about extinction as a *territory* rather than an *event*. Species can accrue extinction debts, the unravelling of communities begins long before the death of the last individual, and "dead clades" are known to walk long after their fate has already been sealed. If extinction is theorised as something both constitutive of the history of life and the formation of species, and as an existential and temporal terrain that must be crossed rather than a cataclysm that can be waited out in suspensive captivity, some transformative conservation projects might be recontextualised as a fairly recent transmutation of phylogenetic and existential strategies for survival developed in interspecies communities. Current shifts in conservation proposals can then be understood as symptomatic of a dawning realisation that one possible response to mass extinction events is to multiply and specialise the pathways, material and temporal, which species can carve through this treacherous terrain. I glimpse in these practices the possibility – distant, perhaps, and never free from the danger of violent power relations – of conceptualising a relationship to endangered species that includes their past as well as their future, as a territory which can be covered both by human interventions and by more than human actors, in their acts of weaving together forms of survival, storing and retrieving their vitality in the bodies of close kin they hybridise with, and provisioning for future transmission.

"How to disrupt patterns of thinking that see the past as finished and the future as not ours or only ours?" is the question asked by Karen Barad in the acknowledgements of *Meeting the Universe Halfway*.[145] It is a question this chapter attempts to find an answer to, by working through the speculative and marginal conservation proposals exemplified by recent attempts at assisted evolution. Analysing conservation biology at its most speculative and transformative is an act of balancing precisely the tensions contained in Barad's question. Reading the interventions enacted by conservation biology as more than mere suspension, the arresting of more than human processes, or the pollution and impoverishment of wildness through captivity opens up to considering the futurity of the

[145] Barad, *Meeting the Universe Halfway*, x.

multiple practices it is composed of, and in particular of its most transformative elements. I understand futurity, here, as the potential interventions into time-scapes contained within transformative proposals; interventions which not only shape futures, but actively create them. Assisted evolution is one example of practices seeking to maintain the ability not merely to survive current conditions (for which free-floating ex situ conservation would be enough) but to truly *inhabit* another future.

This is why in closing, I adopt a speculative approach which actively denaturalises extinction, evolution, and wildness. Rather than attempting to naturalise human interventions into nonhuman processes, as assisted migration and crop wild relative projects do, assisted evolution mobilises a remade concept of the wild, emptied of Romantic connotations of untouchedness or independence but also fundamentally different from what Friese calls species 2.0, remade from the inside out and standing as a testament to unbridled human ingeniousness and mastery.[146] The careful negotiations taking place around slippery coral agents, their disproportionate readiness to acclimatise to laboratory conditions, and their ability to form multiple kinds of collaborations, gives us an intriguing model – still limited by a milieu just as impoverished as the one currently sustaining crop wild relative conservation, but perhaps just as able to subvert this milieu – for thinking about what Baptiste Morizot calls the "balanced interdependence" of the wild.[147]

Conservation practices which understand themselves – or could be read against themselves – as interventions animating the material and temporal agency of endangered species show what shouldering the work that goes into making, maintaining and transforming a species and its relations could look like, once it is understood that that work, and the future time-scapes it opens up to, is neither *not ours*, nor *only ours*. Denaturalising here means refusing a hyperseparation which would allow technological and scientific interventions to be cast as pure or innocent, as an act which either does not leave its marks in the evolutionary histories of various species or creates entirely abstract laboratory artefacts which can be manipulated without any responsibility toward their relational context. Surviving extinction by evolving has, perhaps, *never been natural*; what is at stake is not to condemn the artificiality of speculative conservation as a violent break

[146] Friese, *Cloning Wild Life*, 91.
[147] See Morizot, "Le Devenir Du Sauvage à l'Anthropocène."

in the natural order of things, but to characterise more precisely what kind of work it does and how well it collaborates with nonhuman labour and relation-making.

Conclusion

Throughout this thesis, I have examined recent and emerging transformative conservation proposals as evidence of recent shifts in conservation biology, where emerging concerns about the catastrophic changes wrought on the planet by extractivism and colonial exploitation are repatterning the practices and technologies of the field. While conservation biology is still relatively young, marked by complex and sometimes tumultuous attempts at unifying a set of eclectic scientific disciplines and defining its own objects and principles, it is also informed by a longer history of interventionist techniques of power and knowledge – agriculture, horticulture, colonial botany – which are reactivated in contemporary discussions concerning where conservation is or should be headed. After decades of subscribing to the prevalent "ark paradigm", conservation is returning to forms of experimentality that shed the restrictions and boundaries set by its founding figures, and that instead increasingly align with the vocabulary and politics of bio-, geo- and genetic engineering.[1]

In each chapter structured around a case study – assisted migration, crop wild relative conservation, and assisted evolution – I have attempted to present a reticulated, non-linear and individualising analysis of the material and conceptual politics at play. This follows the Foucauldian proposal to analyse discourses not in terms of temporal continuity but as fields and territories: "once knowledge can be analysed in terms of region, domain, implantation, displacement, trans-position, one is able to capture the process by which knowledge functions as a form of power and disseminates the effects of power."[2] Doing so also allows one to treat these case studies as interlinked but singular experiments, taking place in the context of a common field but not entirely subordinated to a unified set of concerns, norms and goals. Granulating the contemporary conservationist landscape into singular projects and paying finer attention to the variety of futures they are constituting and rehearsing also allows one to attend to what Hinchliffe calls "a careful political ecology," suited to conservation practices that "cannot

[1] See Soulé et al., "The Millennium Ark."
[2] Foucault, *Power/Knowledge*, 69.

simply be about present presence, the gathering up of all that matters, once and for all, and then devising means of rendering them eternally present," but instead work with reconstituted natures, unfinished matters, and provisional categories.[3]

In each instance of transformative conservation examined here, I have investigated the specific biopolitical categories structuring the proposed interventions into nonhuman lives, bodies and ecosystems. Assisted migration participates in a form of environmental governmentality that has shifted from bounded territorial concerns to the need to securitise populations and ensure their circulation, and in so doing enacts a form of horticultural management combined with the neoliberal ambition to govern through disorder. In crop wild relative conservation, the convergence of agricultural and conservationist concerns informs the heterogeneous population now managed by conservation scientists and plant breeders, in which two categories of species – wild and domesticated – are brought together to cooperate. The locus of management thus shifts to the gap between categories of plants, and power is exercised through the relations between species. Assisted evolution is based on scientific developments that dismember corals into their genetic and metabolic components, potentially reifying these complex creatures into artefacts; at the same time, it makes extensive use of emergent and complex properties of coral bodies, in particular of their combination of reproductive modes and their ability to move fluidly from one taxonomic category to another.

But my approach has been double-pronged, in that I have also tried to tease out the oppositional quality of each of these projects, and to follow what Viveiros de Castro calls the "sometimes surprising unintentional effects of bio-, socio-, and geo-engineering actions."[4] In negotiating and composing with recalcitrant subjects, transformative conservation projects reckon with the patchiness of available biological knowledge and the impossibility of establishing frictionless forms of mastery. I have proposed to read the accidents and difficulties of implementing these projects as revelatory of a tendency to constitute tentative, partial and implicit cosmologies in the act of planning or conducting research projects. Assisted migration proponents rhetorically justify their interventions by making extensive reference to deep-time history and prehistoric human-aided dispersal, a discursive strategy that I analyse as a re-storying of nonhuman movement and conjoined migrations in which temporalities can be contracted, stitched

[3] Hinchliffe, "Reconstituting Nature Conservation."
[4] Viveiros de Castro, "On Models and Examples," S298.

together, and ultimately used to justify the cyclical return of species to deep-time ranges, transforming their evolutionary past into their future. Crop wild relative conservation, even as it imposes the structures of agricultural power on wild plants, also reprises attitudes and techniques more akin to hunting practices than fully realised pastoral power, and reveals domestication as a category that both orders and is problematised by contemporary attempts to replay and readjust Neolithic processes – or at least what these processes are understood to be. Finally, assisted evolution reveals the possibility of thinking about reef ecosystems as fully denaturalised products of nonhuman work, and by extension of any form of kinship as the sustained labour of weaving relations. In so doing, it models the possibility of thinking about technoscientific interventions as a form of labour that is neither salvational nor hegemonic but a partner in the social and temporal transactions that may sustain coral reefs across the treacherous terrain of a sixth mass extinction event.

The research conducted in this thesis will hopefully contribute to the existing literature on conservation biology in the environmental humanities. Conservation practices, and in particular those that arise in the liminal spaces of captive breeding and experimental laboratories, have been the object of increased scholarly interest in recent years (as evidenced by the work of Friese, Lewis-Jones, Harrison and Van Dooren, among many others).[5] In marked contrast with earlier critical scholarship on environmentalism, whose centre of gravity was the ontological politics of in situ conservation and its Romantic attachment to an independent nonhuman nature, and to recent work trying to impose the same critical framework on ex situ institutions, the environmental humanities are increasingly engaging with what happens in a space in which relationality is already assumed and practiced, and attending to the effects and ramifications of this shift.[6] The case studies that form the backbone of this thesis are all relatively recent developments in conservation biology, as evidenced by the fact that most of the projects cited are still

[5] See for instance Friese, *Cloning Wild Life*; Lewis-Jones, "Holding the Wild"; Thom Van Dooren, "Banking Seed: Use and Value in the Conservation of Agricultural Diversity," *Science as Culture* 18, no. 4 (December 2009): 373–95; Sara Peres, "Saving the Gene Pool for the Future: Seed Banks as Archives," *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 55 (February 2016): 96–104; Breithoff and Harrison, "From Ark to Bank."

[6] Ex situ conservation was the focus of much writing on wilderness thinking in the 1990s, of which William Cronon's work is emblematic (see William Cronon, "The Trouble with Wilderness; Or, Getting Back to the Wrong Nature," *Environmental History* 1, no. 1 (1 January 1996): 7–28). On the ongoing critique of ex situ conservation as perpetuating supposed nature/culture divides, see for instance Braverman, "Conservation Without Nature."

ongoing and that new studies and proposals are still being published as of the writing of this manuscript. While they have attracted some attention outside of conservation circles[7], these projects are still relatively under-studied, and my hope is that this research will enrich the discipline's inquiries into this field by providing fresh material and new theoretical trajectories for future studies.

[7] See for instance Montenegro de Wit, "Stealing Into the Wild"; Van Dooren, "Moving Birds in Hawai'i"; Filbee-Dexter and Smajdor, "Ethics of Assisted Evolution"; Smith, "(A)wake for the Passions".

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