Biodiversity Conservation in the Context of Synthetic Biology

Meeting Report

December 1-5, 2015

The Rockefeller Foundation Bellagio Center – Bellagio, Italy

Contents

Cover photo credit: Jennifer Luedtke

Group Photo

First row – *left to right*: Liz Bennett, Kent Redford, Drew Endy, Gernot Segelbacher, Rob Carlson, Claudio Campagna, Phil Seddon, Keith Wheeler, Bruce Hay, Lydia Slobodian, Jennifer Luedtke, Ron Sandler.

Second row – *left to right*: Tom Brooks, Todd Kuiken, Bob Friedman, Toni Piaggio, Simon Stuart, Aroha Te Pareake Mead, Ryan Phelan, Cyrie Sendashonga, Marina Rosales Benites De Franco.

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About the Meeting

Framing Statement

Synthetic Biology (SB) is an emerging field of science that has the potential to provide solutions to many of the world's most difficult challenges, including the crisis of global biodiversity loss. However, it may also pose risks to the goals of conservation and sustainable development thereby deepening the current crisis. Particular areas of concern include the potentially positive or negative impacts of ecosystems with artificial components and engineered species, and how this affects the resilience of existing species and ecosystems.

At present, the conservation community is ill-prepared to address the challenges and take advantage of the opportunities posed by SB. As leaders in the global conservation movement, the International Union for Conservation of Nature (IUCN) is well-placed to provide leadership in this new realm by developing an initiative on SB and biodiversity conservation.

This workshop will address the aspects of SB that relate to conservation and sustainable development. It will consider ways in which an IUCN initiative could influence the field of SB at a stage when it is still susceptible to change.

Goals

1. Develop an understanding of why SB is relevant to IUCN's mission and vision, and actions required by IUCN in response;
2. Identify five ways to influence developments in SB to increase the potential for its positive impact on conservation; identify five potential ways SB developments could conflict with conservation goals;
3. Discuss the future of SB and conservation in order to decide the best way to interact with/influence it from the perspective of the international conservation community, particularly the IUCN community.

Guiding questions

Discussions will be guided by these main questions:

1. How could SB approaches be made beneficial to conservation, sustainable development and human livelihoods?
2. What might be the unexpected impacts that SB applications might produce to conservation and how could they be mitigated?
3. Under what circumstances should SB approaches not be used in conservation applications?

Expected outputs

1. A draft resolution on SB for consideration at the 2016 IUCN World Conservation Congress. Such a resolution would be voted on and hopefully adopted by IUCN Members, including governments and non-governmental organizations.

2. A report for submission to the CBD in the context of the recently started consultation on SB, and to the IUCN SSC Specialist Groups regarding SB and conservation under the IUCN umbrella.

The Bellagio approach

The Bellagio Center encourages a dynamic intellectual exchange among meeting participants rather than a fixed agenda based on individual presentations followed by questions and answers. Presentations and contributions during discussions are therefore kept short in order to promote dialogue and interaction.

Meeting Summary

Day 1: Introductions and background

The broader context of the meeting – synthetic biology and the nature of IUCN – was introduced through the following presentations: *Building our biological future*, by Rob Carlson and *An introduction to IUCN*, by Cyrie Sendashonga.

IUCN Commissions in attendance explained the history, impact, and SB-related concerns of their work: Commission on Environmental, Economic, and Social Policy (CEESP), by Aroha Te Pareake Mead (Chair, CEESP); Commission on Education and Communication (CEC), by Keith Wheeler; World Commission on Environmental Law (WCEL) and Environmental Law Centre (ELC), by Lydia Slobodian; and Commission on Environmental Management (CEM), by Marina Rosales Benites De Franco.

Lessons learned at previous meetings were summarized by Kent Redford (*Synthetic Biology and Conservation* at Clare College in Cambridge, UK on April 9-11, 2013) and Ryan Phelan (*New Genomic Solutions for Conservation Problems* in Sausalito, California, USA on April 6-9, 2015).

Todd Kuiken provided an introduction to the competitions run by the International Genetically Engineered Machine (iGEM) Foundation. These began in 2003 at the Massachusetts Institute of Technology (MIT) and now reach high school, university, and graduate students from more than 30 countries (www.igem.org).

Before gathering group feedback on the topics to address over the subsequent two days, Simon Stuart (Chair, SSC) presented the goals and challenges of global species conservation efforts – and those of the IUCN Species Survival Commission (SSC) in particular – and Claudio Campagna initiated a conversation about values and the importance of giving careful consideration to the words and language we use.

Day 2: Group exercises

Group exercise 1: Collaboration between the Synthetic Biology and conservation communities

Participants shared impressions and feedback on the proceedings of the first day, and then split up into three working groups focused on the major threats faced by global biodiversity: 1) habitat loss and

unsustainable use, 2) invasive species and disease, and 3) climate change and pollution. The assignment was to outline possible collaborations between the conservation and SB communities, describing not only the benefit provided by an SB solution, but its value to conservation, associated challenges, and the methods employed to mitigate potential adverse effects of the solution.

Group 1: habitat loss and unsustainable use

Members: Drew Endy, Keith Wheeler, Kent Redford, Marina Rosales Benites De Franco, Phil Seddon, Tom Brooks

General point: need a framework for assessing the net impacts – and undertake this assessment, and produce emerging guidelines

1) *Habitat conversion: SB feedstocks*

SB needs feedstocks and so could place an additional load on biology. What might these feedstocks be? Could be sugar (beets, cane, potato, wood), light, gas (methane, biogas).

Benefits of SB to biodiversity conservation:

- Could be a reduction (e.g., wormwood – x30 less area needed)
- Could shift production into more "efficient" environments e.g., marine? – thereby reducing pressure on terrestrial environments
- Reduction in footprint of fossil fuel industry (e.g., in Middle East, Wyoming, Ecuadorian Amazon) + associated bushmeat harvest
- Reduced fossil fuel usage in agriculture and so reduced habitat loss to climate change

Risks of SB to biodiversity conservation:

- Potential expansion (x3?) of land area for sugar cane production
- Accelerated by demand for "green" products
- Increased water usage

2) *Habitat conversion: agriculture & forestry*

Population growth and consumption, prospect of 10bn people in world. Agriculture on Mars?

Benefits of SB to biodiversity conservation:

- Increase resistance to pests and therefore decrease pesticide use
- Could decrease extensification through intensification (agriculture, livestock, aquaculture); high productivity plantations to reduce pressure on natural forest (land sparing)
- Increasing wealth could decrease land conversión
- Not "synthesising" biology, but rather re-purposing natural biology – celebrates biodiversity in support of biotech – "biotopia" – synthetic biology needs biodiversity conservation?

Risks of SB to biodiversity conservation:

- Open new agricultural frontiers through increased productivity and tolerance, e.g., kelp forests
- Does increased productivity reduce footprint, or does it stimulate demand for extensification as well? – this is an issue of governance
- Impacts on rural communities, small farmers (culture of using native crops etc) cf large companies

3) *Habitat conversion: palm oil*

Palm oil is $500/MT so $0.50 /kg; cf sugar $0.34 /kg. Could make palm oil without the palms?

Benefits of synbio to biodiversity conservation:

- Could reduce or take pressure off tropical forest conversion for oil palm

Risks of synbio to biodiversity conservation:

- Carbon has to come from somewhere else – feedstocks issue – but this could be in habitats other than tropical forests
- Stimulate demand for more oil palm (analogy to concern on synbio production of rhino horn or bear bile)
- Increased water usage

4) *Habitat conversion: replacement of agriculture*

Benefits of synbio to biodiversity conservation:

- Entirely new sources of food (e.g., natural gas fermentation – 60% of US houses have natural gas) could reduce demand for agriculture, need for road networks, etc

Risks of synbio to biodiversity conservation:

- Could stimulate additional demand for fossil fuels and water (e.g., fracking)

5) *Habitat conversion: restoration*

Synbio could advance habitat restoration on degraded lands, e.g., to fix soils in severely degraded lands for conservation - or for agriculture (which is likely to be the biggest indirect conservation benefit here)

Benefits of synbio to biodiversity conservation:

- Habitat remediation and restoration (e.g., after gold mining in Peru; oil and gas)
- Genetically modified plants to remove pollution (e.g., poplar trees and heavy metals)

Risks of synbio to biodiversity conservation:

- Modifications to remedial organisms could spread to other species (historical example: kudzu invasion subsequent to introduction for soil stabilisation)

6) *Habitat conversion: refaunation (de-extinction)*

Creation of ecological proxies for missing species

Benefits of synbio to biodiversity conservation:

- Could restore ecological functions
- E.g. not recreate mammoth, but rather engineer Asian Elephants to recreate lost ecosystem
- New Zealand megafauna: bring back moa birds
- Improvements in understanding of evolutionary processes and relationships

Risks of synbio to biodiversity conservation:

- Unanticipated roles in ecosystems, invasive potential, genetic pollution

7) Overharvest: benefits of SB to biodiversity conservation

- Improved aquaculture, protein production could reduce extent of fisheries exploitation
- Sinopodophyllum (Himalayan Mayapple): chemical synthesised from tobacco to take pressure of wild harvest
- Deep-sea sharks and squalene (particular properties unique to the molecule)
- Pet trade: could produce sterile exotic pets (e.g., tropical fish; dwarf pigs) (although highest value are rarest)

8) Overharvest: risks of SB to biodiversity conservation

Could SB substitute overharvest of rhino horn etc? Could make rhino horns on cows (or rhinos without horns)?

- Opening up legal markets which are currently closed, allowing for laundering of the illegal product. Look at risk of unwittingly expanding demand.
- Product might not be widely acceptable to consumers if not wild harvested. Don't fall into trap of surrogate "not as good" as the natural source. Three-D printing horns and doping w/ rhino DNA. Veblen goods: increasing price increases demand.
- Bear bile: does have genuine properties; but additive given cultural perception and so still danger of stimulating demand. Same issue as bear farming.
- See costs of feedstock production
- For pet trade: amplification of dominion of people over nature
- Loss of local income (e.g. from Himalayan Mayapple)
- Decrease in interest in sustainable livelihoods and sustainable management of wild species

Group 2: invasive species and disease

Members: Gernot Segelbacher, Toni Piaggio, Cyrie Sendashonga, Liz Bennett, Claudio Campagna, Rob Carlson, Ryan Phelan, Jennifer Luedtke

Species	Problem	Solution/execution/benefits	Value of benefits	Risk of not using technology	Risks of technology	Mitigation
Caracara/Albatross and other ground nesting seabirds in Falklands	Invasive rodents brought by humans to the island are predating on nests of ground nesting birds. Current management with rodenticide means Caracara and others is collateral damage: land crabs (primary prey) ingest the rodenticide and ends up kills the birds	Eradication of invasive rodents through genomic solutions Benefits:	High value because these are endemic species and a highly valued threatened habitat	Run out of time to find other solutions that prevent a higher threat level and eventual exinction	1) Transgenic rodents move to other islands or mainland (low) • Difficult to swim between islands • Uninhabited island • Isolated from continents • Limited vessels run by research staff with possible biosecurity protocol	1) Reversibility (gene drive)
		1) Lowering mortality and prevents extinction of Caracara			2) Hybridisation with endemic rodents on the mainland • Uninhabited island isolated from continents	2) Population modelling to determine the level of risk/probability
		2) Success in reproduction and prevents extinction of ground nesting birds			3) Societal rejection of project • Uninhabited island	3) Upfront modelling and study of threat, longterm monitoring
		3) Restoration of native ecosystem				
Native Hawaiian birds	Avian malaria in Hawaii infecting remaining native birds from invasive mosquitos; invasive pig wallows facilitate mosquito breeding; climate change is allowing mosquitos to move to higher elevations removing the last	Eradication of invasive mosquito through genomic solutions Benefits:	High value because these are endemic species and a highly valued threatened habitat	Run out of time to find other solutions that prevent a higher threat level and eventual exinction	1) Transgenic mosquitos move to other islands or mainland	1) Reversibility (gene drive)
		1) Prevents extinction of highly threatened bird species			2) Societal rejection of project: both inhabitants and international community	2) Population modelling to determine the level of risk/probability
		2) Does not require eradication of invasive pigs			3) Preventing evolutionary processes	3) Upfront modelling and study of threat, longterm

	refuge of these birds	in same project			from taking place that could eventually give these bird species immunity to avian malaria	monitoring
		3) Gives birds better chance in adapting to climate change				
Amphibian species worldwide (especially high-altitude species associated with streams and threatened habitats)	Chytridiomycosis strains are lethal to many species and are thought to be invasive where mass mortality events have been recorded; global exinction and devastating declines have been recorded in amphibian communities in many places around the world	Genomic solution that targets the virulence of the fungus Benefits: 1) Prevents ongoing and future population declines 2) Slows/prevents global species extinctions	High value because these are highly threatened species and could prevent spread to other regions	Not applicable/measurable	Too many unknowns in terms of knowledge of pathogen (incl. genome, strains), function of fungus in ecosystem, and distribution of solution Unintended consequence: potential value of Bd strains to some species (co-evolution)	

Group 3: climate change and pollution

Members: Bruce Hay, Aroha Mead, Todd Kuiken, Simon Stuart, Ron Sandler, Lydia Slobodian, Bob Friedman

Key words – mitigation, adaptation

1) *Algae reducing CO2 emissions*
   - Replacing the feedstock for livestock and have a beneficial climate impact.
   - If replacing beef with fish in human diet, then replacing the feedstock for aquaculture might also have a beneficial climate impact.
   - Biofuels from algae to reduce carbon intensity by, in a pond rather than a field. Can you do better than sugar cane in terms of energy inputs, use of products, pollution caused, costs? Risks of spread of algae by birds, etc. How invasive would the engineered algae be? Can ponds be put in places where you can't grow anything else (degraded land) or jeopardize biodiversity or prevent better alternatives of land use? Would these ponds displace existing biofuels or be additive? It is important that it does not another pressure on land or water that is important for other uses including biodiversity conservation. This requires a life-cycle assessment than can look at all the implications / impacts (including social ones) on carbon vs water use to assess the real benefits. In subsequent plenary discussion, Rob Carlson stated that he had looked into the algal ponds issue and had found that it would not be a viable alternative.

2) *Coral reefs*

Some general discussion: It is known that sea grasses can locally reduce acidity. What limits sea grasses, what is their mechanism of CO2 uptake, can it be enhanced? Is it possible for corals to create more acid-resistant CaCO3. Are there already corals in more acidic environments? Look at the paleo-record of corals to see if it sheds light on how corals handled acidity in the past. Obviously, address acidic agricultural run-off into the ocean where it is a problem.
It was agreed that it was an important area of research to see if there are opportunities to use synthetic biology to address the threats of ocean acidification to coral reefs. Can synthetic biology regulate pH in coral reefs (through engineered micro-organisms)? Or is it possible to re-engineer corals? A statement from IUCN supporting such research would be helpful.

3) *Micro-plastics in the ocean*

It was agreed that it would probably be easiest to address this problem by changing the character of plastics on the market. Synthetic biology research could be used to describe and understand the problem and its interaction with the biological world in more detail. A statement from IUCN supporting such research would be helpful.

4) *Engineered algae to remove pollution from water*

Not really discussed in depth. Nature can perhaps figure out how to do this in any case.

5) *Removal of oestrogen in water ways*

Not really discussed in depth. Very early days in terms of understanding the issue, but could be a useful area of synthetic biology research.

6) *Engineered trees to sequester more carbon*

Not really discussed in depth. So far this has been done by more traditional genetic engineering.

7) Replacing things made from petroleum with biological products, especially engineered plants
This would have a positive climate impact if we remove less oil from the ground, and sequester more carbon from the atmosphere.

8) Novel crops being less dependent on fertilizers, pesticides and herbicides
A possible benefit

9) Very high productivity forests based on modified trees
Trees with less lignin ("floppy trees") can be used more easily and with less energy as biofuels, or for pulping, requiring less land than current plantations.

10) SB to help species adapt to climate change
Possibly, not really well understood yet.

Group exercise 2: Engaging stakeholders

A second group exercise considered the concerns of two different stakeholders vis-a-vis SB: 1) the global conservation community, 2) local stakeholders.

Group 1: addressing the concerns of the global conservation community

Summary
- Only one concern that was unique to SB
- Solutions exist already 1) because the concerns apply to other technologies and there have been attempts to address them – we can learn from these, adopt their solutions and avoid their pitfalls, 2) risk assessment and management frameworks, guidelines, international conventions that could be employed rather than re-inventing the wheel, 3) getting people talking to each other
- Asking the SB community what concerns we should have or have missed
- This is more an issue of quantitative rather than qualitative changes: more people doing this faster and in greater volume

Unique to SB
- Moral hazard: De-extinction negates the reality that extinction is forever and take the urgency out of conservation action

Relevant to other technologies/issues
- Something (habitat or organism) culturally created cannot replace something naturally created (through evolution): technology cannot replace nature
- Technology will get out of control with negative consequences (transgenes appearing in wild species; hybridisation)
    - What if people want to release a novel organism they created to increase biodiversity? (Example of the *weeogg* organism)

- Technological fix that does not really solve the problem and does not require people to change their behaviour
- Funding could be taken away from current conservation priorities
- Re-introduction of "de-extinct" species that do not have a habitat anymore
- Private sector (that does not have the interests of society) that owns the technology will have disproportionate power in decision-making
- Who gets to make the decisions? Both the large players and small players could make decisions for everyone else
- Decisions that have consequences that extend beyond the jurisdiction of the decision-maker
- Impression that impacts and decisions are not reversible
- Unknowns: not enough study on the impacts
- Technology could impair evolutionary processes, which we value
- SB solutions could be overused or misused
- SB is considered a silver bullet and other methods are not considered – or even developed
- Silo thinking of conservation community may prevent them from adequately considering alternative methods or technologies, such as SB, that may provide alternative and appropriate solutions
- Restricting access to the technology or products required could end up creating/encouraging a black market
- SB will perpetuate cycles that will require continuing intervention and new approaches
- If biological information can be shared without a biological sample (as computer code), then regulatory systems could lose control over biological information
- Concerned that SB will facilitate the eradication of pests and undesirable organisms, and the temptation to do so would be irresistible
- The conservation community may not know enough about proposed technology
- Existing regulations may not cover the technologies or organisms, components and non-living products of SB that are being proposed

How has IUCN managed other concerns around other emerging and new technologies or methods?

Solutions

- Increase awareness and improve communication/language of what is being proposed by SB technology: harnessing the precision of nature to improve existing solutions
    - Do not be naïve in thinking that communication can address everyone's concerns or even be effective (hasn't been the case for climate change, GMOs, etc)
    - Early success-stories could be influential in helping people understanding what is being proposed and what problems could be solved
    - Hosting and facilitating venues and events that provide safe places were our colleagues can learn about SB
- Decision makers – large and small – need guidelines
    - Risk analysis, assessment and management framework that requires the variety of attitudes towards risk to be taken into account and quantified, this allows the practitioner to identify alternatives
    - Decision tree that helps to identify other potential or more appropriate solutions

- Biosecurity ethical codes are required for all who use and develop SB technology
    - Could be done through a new or existing conventions/protocols;
    - Codes of conduct have already been developed by people who call themselves synthetic biologists;
    - iGEM has been teaching respect for codes of conduct and best practice to students in their competitions [link to this information]
- Precedent to the moral hazard exists: frozen zoos; wilderness should not be tampered with

Group 2: involving local stakeholders in developing conservation projects using synthetic biology

The group worked through the Hawaii avian malaria example. The stakeholders include indigenous people, and a strong anti-GMO movement. There has been a lot controversy, for example with genetically modified taro on which there was very limited stakeholder consultation. Now native ohia trees on Hawaii are being killed by a *Phytophthera* fungus. The conservation community on Hawaii is well-organized, with 2-3,000 people meeting annually. So there is a place where the conversations could start. Indeed Samuel M. ʻOhukaniʻōhiʻa Gon III ("Sam"), working for TNC in Hawaii, is involved, and is well-respected in indigenous communities.

Pluses for controlling avian malaria and/or mosquitos

- The pathogen is not a food
- Pathogen is invasive
- Birds are loved, endemic, and very threatened
- People hate mosquitoes, they carry diseases
- Contained experiment
- The problem is human-caused

Minuses for controlling avian malaria

- Unnatural interventions and less desirable, nature has natural mechanisms
- Perhaps not viewed as a priority by some groups
- Lack of trust from indigenous communities

For each project we would need to identify all the stakeholders (use existing stakeholder analysis techniques/guidelines). There would need to be very early consultation and discussion with stakeholders, not just presenting a single solution, but talking through options. For example, Maori research has principles, such as giving back, reciprocity, long-term relationships, sharing research outcomes in all phases of the research, etc., and approaches such as these should be used. People should be contacted early and often, as Sam, referred to above, has been doing. It is important to avoid an "us-them" focus in discussions.

Some other consideration regarding stakeholders not related to the Hawaii example
We need to talk to the young now who will be the future decision-makers in 20-40 years' time. We also need to focus on those who give the technology, as well as on those who receive the technology. There will need to be engagement with faith-based organizations. Other stakeholders include senior policy-makers (and all defenders of the status quo), the Convention on Biological Diversity, and others.

Day 3: Decisions

Following general thoughts and reports of specific conversations that took place in the margins, a list of topics and desired outcomes was assembled and addressed one-by-one. This list was initially compiled using the feedback collected on day 2 and completed through group discussion.

Meetings

- Society for Conservation Biology 2017 meeting

No.	Lead	Decision	Timeline
1	K Redford, G Segelbacher	Act as focal points on this meeting and look into organising a symposium on conservation and SB	Ongoing

- IUCN World Conservation Congress 2016

No.	Lead	Decision	Timeline
2	All	Informal gathering of meeting participants during excursion day at the Botanic Gardens and/or in days following the Congress	8 September 2016
3	R Phelan, G Segelbacher	Follow up on results of IUCN decisions on workshop proposals for 2016 WCC	Ongoing

- April 2016 SBSTTA meeting

No.	Lead	Decision	Timeline
4	All	Submit comments on the CBD AHTEG report to Sonja Pena Moreno (Sonia.PenaMoreno@iucn.org)	25 January 2016
5	S Stuart	Stay in touch with Andrew Bignell (Chair, CBD SBSTTA) on these issues	Ongoing

- 7th Synthetic Biology meeting (2017) in Singapore
- iGEM competitions – sponsoring a prize for best conservation project or a team that would work on conservation projects; serve as judge; provide IUCN contacts with expertise to the teams
- Get involved with Science Foo Camp (Sci Foo)? https://en.wikipedia.org/wiki/Science_Foo_Camp

No.	Lead	Decision	Timeline
6	R Carlson, T Kuiken, R Friedman	Report back with specific proposal on IUCN engagement with iGEM, 7th Synthetic Biology meeting, and Sci Foo camp	Done
7	R Phelan	a. T Kuiken and D Endy to continue conversation on iGEM and find out whether sponsorship requires a financial contribution b. R Carlson to look into potential opportunities with Sci Foo	In due time
8	D Endy	Report back on possibility of having speakers/sessions on conservation at the 7th Synthetic Biology meeting (2017) in Singapore	In due time
9	R Friedman	Raise awareness within the synthetic biology community of the potential contributions synthetic biology might make to biodiversity	In due time

		conservation. Once written materials are available from the writing group, distribute summaries to various synthetic biology community listserves and newsletters, e.g., SyntheticBiology.org, SynBioBeta newsletter, Insect Genetic Technologies Network, etc.	

Written publications

- Paper in ecology journal (e.g. TREE) + Statement on SB and conservation + Glossary of SB terms + List of conservation issues for SB to address (both from this meeting and from a larger group)
    - How to capture and facilitate ongoing input, case studies, ideas of issues for SB to address, etc from readers and the larger community? Website?
        - R Phelan suggested that interested meeting participants join the Long Now listserv of SB and conservation scientists

No.	Lead	Decision	Timeline
10	P Seddon, G Segelbacher, T Piaggio	Report back with outline, format and content of paper on SB and conservation, building on and drawing from existing documents and previous meetings; including case studies, early and potential areas where SB could contribute to conservation, and a glossary of terms.	Done

Report from P Seddon, G Segelbacher, T Piaggio:

- Opinion piece identified as best type of submission to TREE – should not be a meeting report, but rather be a reflection of where the group is at with issue;
- Constraint of 3 authors for opinion piece in TREE: could have third author as the cons and SB working group – paper team to discuss options with journal editor;
- Timeline:
    - Outline and title: done
    - Proposal sent to editor: by 18 December 2015
    - First draft ready for comment: by 1 Feb 2015
    - Draft comments due: by 13 Feb 2015
    - Submission: July-September 2015
    - Possible revision and resubmission: October 2015

- Guidelines on SB from IUCN
    - P Seddon successfully navigated the moratorium on GMOs in the development of the draft SSC De-extinction Guidelines, which could serve as a template for the approach to SB guidelines. However, perhaps this should not be included yet in the WCC motion. R Phelan: could guidelines on a subset of SB be started (e.g. invasive species). P Seddon: could a statement of support be drafted that groups types of SB interventions/conservation issues?
    - Could the Wildlife Heath Guidelines be updated to include a chapter on SB? Could the same be done for invasive species, etc?

Policy arena

- IUCN GMO resolutions; see following documents:
  - RES 2.31 Genetically Modified Organisms and biodiversity (https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2000_RES_31_EN.pdf);
  - RES 3.007 A moratorium on the further release of Genetically Modified Organisms (GMOs) (https://cmsdata.iucn.org/downloads/wcc3_res_007_1_.pdf);
  - RES 3.008 Genetically Modified Organisms (GMOs) and biodiversity (https://cmsdata.iucn.org/downloads/wcc3_res_008_1_.pdf);
  - Current Knowledge of the Impacts of Genetically Modified Organisms on Biodiversity and Human Health: An information paper (2007) at https://cmsdata.iucn.org/downloads/ip_gmo_09_2007_1_.pdf;
  - Genetically Modified Organisms and Biosafety: A background paper for decision-makers and others to assist in consideration of GMO issues (2004) at https://portals.iucn.org/library/efiles/documents/PGC-001.pdf.

No.	Lead	Decision	Timeline
11	L Bennett	Draft motion for the 2016 IUCN WCC calling for the three current IUCN resolutions on GMOs to be resolved/reconciled through a programme of work up to 2020; keep non-technical, focus on need for work, call for new policy rather than guidelines; M Hoffmann (SSC Senior Scientist) to advise on process	12 February 2016

- UN Annual Global Sustainable Development Report (GSDR) to accompany SDG goals
  - A new IUCN permanent observer to UN has been hired and has requested support from C Sendashonga and T Brooks on developing an issue brief addressing SB (few pages long) – could be a summary of the TREE paper; this could begin a process of informing UN ambassadors on the issue

No.	Lead	Decision	Timeline
12	?	With input from meeting participants and content from draft TREE paper, prepare a UN issue brief on SB, showing the implications from a sustainable development perspective (1500 words) - T Brooks, C Sendashonga to have advisory role only	18 January 2016 or the following year

- IUCN participation in CBD discussions on SB

Future IUCN engagement

- Future role of the group convened at Bellagio

No.	Lead	Decision	Timeline
13	All	Participants of this meeting should comprise an informal working group to help guide processes in the lead up to the 2016 IUCN WCC; the WCC	Ongoing

		motion should formalize the group	

- Facilitated mediation between SB and conservation

No.	Lead	Decision	Timeline
14	A Te Pareake Mead, K Wheeler	Samuel M. ʻOhukaniʻōhiʻa Gon III ("Sam"), working for TNC in Hawaii in Hawaii and possibly former Keystone President dialoguing with working group on SB	Ongoing

- IUCN structural response to SB: single group + add to existing groups
  - A WCC motion would call for a working group; have a group within an existing IUCN structure to get things moving (e.g. starting in the SSC Conservation Genetics Specialist Group) with the purpose of harmonizing guidelines around conservation and SB by engaging all IUCN Commissions
  - Ecosystem and Protected Area guidelines would also need to be looked at in this context

No.	Lead	Decision	Timeline
15	R Phelan, M Rosales Benites De Franco	Discuss applications of SB to ecosystems and protected areas and report back to working group	Ongoing
16	R Phelan, G Segelbacher	Discuss applications of SB to genetic diversity and report back to working group	Ongoing
17	K Wheeler	Convene an informal group to begin communicating conservation and SB; the role of the group will be clarified by the WCC motion	Ongoing

- SB organisations joining IUCN
- Tool development (e.g. information in the Red List that could guide SB practitioners)
- Synthetic Biology and oil palm

No.	Lead	Decision	Timeline
18	L Bennett, T Kuiken	Research applications of SB to conservation issues around oil palm and report back to the working group	End January 2016

Working group communications

No.	Lead	Decision	Timeline
19	J Luedtke	Create listserv to facilitate working group communication; include individuals invited, but unable to attend Bellagio meeting	Done
20	J Luedtke	Create space where working group documents can be shared and stored; working group members to notify each other through the listserv when new material is added	Done

Agenda

The meeting coordinators will adapt this agenda according to the Bellagio approach above and based on the significant issues that arise during discussions.

Arrival day – Tuesday, December 1st

Time	Event
09:00	**Check-in opens**
13:00-14:00	Lunch (served at 13:00 sharp)
19:00-19:30	Cocktails & welcome from Bellagio Center Managing Director, Ms Palacia Pilar
19:30-20:30	Dinner (served at 19:30 sharp)
21:00	**Check-in closes**

Day 1 – Wednesday, December 2nd

Time	Event	Presenter
08:00	**Breakfast**	
09:00	**Session 1: Introductions and discussion background** Introduction: goals and structure of meeting	Simon Stuart, Claudio Campagna
09:15	Defining synthetic biology	Rob Carlson
09:30	IUCN and SB: perspectives from the Commissions	Commission representatives
10:10	SB and conservation: Round 1: Lessons from Cambridge 2012 Meeting	Kent Redford
10:25	SB and conservation. Round 2: Lessons from San Francisco 2015 meeting	Ryan Phelan
10:35	The place and role of IUCN in the context of SB	Simon Stuart
10:45	What does each participant envision as his-her contribution to the goals of the meeting?	Everyone (2-3 mins each)

11:00	**Coffee Break**	
11:30	**Session 2: Elucidating values: SB and the concept of Nature** A cost-benefit analysis relative to the use of SB for conservation and sustainability requires the discussion of a value scenario. An exercise will be proposed to surface the value systems of individual participants.	Claudio Campagna
11:40	Discussion Guiding questions: • How could SB modify the concepts of Nature, species and conservation? • Will SB add a new value paradigm? • How could SB enhance the utilitarian and non-utilitarian values of nature? • What are the ethical challenges the conservation movement faces regarding the application of SB solutions to conservation challenges?	
13:00	**Lunch**	
14:00	**Session 3: SB and species** **Conservation status of species according to the IUCN Red List of Threatened Species** IUCN's work on species is unprecedented. The IUCN Red List of Threatened Species is the most trustworthy source of information on the conservation status of biodiversity. The pros and cons of SB and species is thus a natural source of opportunity and concerns for IUCN. The organisation also develops knowledge, guidelines and policies on species-related issues, such as reintroductions, invasive species, etc. The potential influence that IUCN may have on the CBD is one of the most relevant paths of actions that may be derived from this meeting. Recently, a task force of the IUCN developed a report on de-extinction that is directly relevant to this meeting (see Appendix 2.1).	Simon Stuart
14:10	Discussion Guiding questions: • What can SB do for threatened species? • What is the relevance of de-extinction in the context of biodiversity conservation? • What are the potential threats and opportunities of SB for species conservation?	
17:30	End of day 1	
19:00	Cocktails	
19:30	**Dinner (served at 19:30 sharp)**	

Day 2 – Thursday, December 3rd

Time	Event	Presenter
08:00	**Breakfast**	
09:00	**Session 1: Discussion on SB, ecosystems and people** SB has the potential to change ecosystems in terms of species structure, composition and function. It may enhance some functions and silence other via the modification of productivity and trophic interactions. IUCN, through its Commissions, plays a unique role in promoting concepts and developing tools for habitat and ecosystem conservation. Guiding questions: • What are the most likely situations in which SB can improve the condition and function of an ecosystem? • How might SB undermine ecosystem management, sustainable use and improved human livelihoods? • How might changes to human well-being through SB advances indirectly impact conservation? • What are the most likely potential applications of SB to climate change impacts on ecosystems?	Simon Stuart, Claudio Campagna
11:00	**Coffee Break**	
11:30	**Session 1: part 2**	
13:00	**Lunch**	
14:00	**Session 2: An institutional perspective within the IUCN constituency** IUCN is a complex network – a union that brings together governments and NGOs – and is making progress towards incorporating the contributions of the private sector to advance its vision and mission. Guiding questions: • How might IUCN seek to influence governments and governance in the context of SB and conservation? • How could IUCN work with NGOs on SB? • How could IUCN help to integrate the role of the private sector and the goals of conservation with regard to SB?	Simon Stuart, Claudio Campagna

15:30	**Session 3: Ethical concerns** SB implies an unprecedented intervention in Nature (species – including humans – and ecosystems). It has the potential to alter the definition of a wild species. As such SB could be a form of cultural selection, between domestication and natural selection. Its consequences are similarly unpredictable, thus interventions imply a risk tied to human will and imperfect understanding. The language of SB can be misleading and yet the species crisis requires urgent corrections, and none of the social, economic and political frameworks are adapting fast enough. It may be after all that a technological intervention is the only practical resort for some of the most damaging aspects of environmental degradation.	Claudio Campagna
15:35	Discussion Guiding questions: • What ethical challenges does the conservation movement face regarding the application of SB solutions to conservation challenges? • What is "good" about SB and what is "bad" in terms of conservation ethics? • What will be considered "good" for conservation and what could hinder conservation values as a result of progress of SB? • What are the principles behind SB and conservation? • How might SB influence the vision of IUCN as an organisation?	
17:30	End of day 2	
19:00	Cocktails	
19:30	**Dinner (served at 19:30 sharp)**	

Day 3 – Friday, December 4th

Time	Event	Presenter
08:00	**Breakfast**	
09:00	**Session 1: Creating leadership capacity in IUCN on SB issues** IUCN is the leading organization in determining the conservation status of global biodiversity, and more recently, of global ecosystems. Yet solutions proposed in conservation emergencies are within the traditional toolkit in conservation biology and sustainability: good practices, strengthening institutions, provide scientific support, promote international policy. It is thus necessary to consider how IUCN might lead global conservation on matters related to this new conservation tool.	Simon Stuart, Claudio Campagna

	Guiding questions: • Will SB create revolutionary solutions to conservation challenges? • How should IUCN prepare for the potential revolution that might be created by SB? • Is the IUCN partnership well prepared to tackle issues concerning SB? • What are IUCN's priorities for a program of work on SB?	
11:00	**Coffee Break**	
11:30	**Session 2: Communicating SB** Guiding questions: • How are the positive and negative impacts that SB may have on conservation being communicated? • How should IUCN communicate the pros and cons of SB and conservation?	Simon Stuart, Claudio Campagna
13:00	**Lunch**	
14:00	**Session 3: Group writing exercise of a draft IUCN resolution** Develop a road map for IUCN and draft a resolution on SB to be considered at the 2016 IUCN World Conservation Congress.	
16:00	**Session 4: Concluding remarks and follow up**	Simon Stuart, Claudio Campagna
17:30	End of day 3	
19:00	Cocktails	
19:30	**Dinner (served at 19:30 sharp)**	

Departure day – Saturday, December 5th

Time	Event
08:30	**Check-out <u>before</u> this time; departures from center should be no later than 10:00**

List of Participants

Name of person	Affiliation	Profession	Email address
Drew Endy	Stanford University	Bioengineer/ Synthetic biologist	endy@stanford.edu
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Ryan Phelan	Revive and Restore	Synthetic biology advocate	ryan@longnow.org
Simon Stuart	Chair, IUCN Species Survival Commission	Science and policy specialist; co-organizer	Simon.stuart@iucn.org
Todd Kuiken	Woodrow Wilson Center		todd.kuiken@wilsoncenter.org
Tom Brooks	Head of Science and Knowledge, IUCN	Conservation biologist	Thomas.BROOKS@iucn.org

Appendices

Appendix 1: Background

The International Union for Conservation of Nature

IUCN helps the world find pragmatic solutions to our most pressing environment and development challenges. IUCN's work focuses on valuing and conserving nature, ensuring effective and equitable governance of its use, and deploying nature-based solutions to global challenges in climate, food and development.

IUCN supports scientific research, manages field projects all over the world, and brings governments, NGOs, the UN and companies together to develop policy, laws and best practice. It is the world's oldest and largest global environmental organization, with more than 1,200 government and NGO Members and almost 11,000 volunteer experts in some 160 countries. IUCN's work is supported by over 1,000 staff in 45 offices and hundreds of partners in public, NGO and private sectors around the world.

IUCN is structured around six Commissions that provide the Union with sound know-how and policy advice on conservation issues: *Commission on Education and Communication (CEC), Commission on Environmental, Economic and Social Policy (CEESP), World Commission on Environmental Law (WCEL), Commission on Ecosystem Management (CEM), Species Survival Commission (SSC), World Commission on Protected Areas (WCPA).*

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Appendix 2: Precedents

1. Meetings

1.1 Planning meeting for DC symposium

Challenges and Opportunities in the Emerging Field of Synthetic Biology
Rockefeller Center
Bellagio, Italy
The National Academies
OECD
The Royal Society
October 22-25, 2008

In 2009, the National Academies, together with the Royal Society, and the Organisation for Economic Co-operation and Development (OECD), held a symposium on the *Opportunities and Challenges in the Emerging Field of Synthetic Biology (http://sites.nationalacademies.org/pga/stl/PGA_050738.htm)*.The meeting drew speakers and attendees from around the world including Europe, Australia, Asia, Africa, South America, and the United States. Speakers and participants commented that while they had attended

other meetings on synthetic biology none had attended one with such a rich array of expertise and diversity both in terms of perspectives and cultures. A number of scientists commented that the meeting was a "landmark" event as it brought together scientists and engineers with policy-makers for in-depth discussions about both science and policy. The meeting received media attention, both in print and on the radio.

The success of the 2009 International Symposium can be directly attributed to the planning meeting held in Bellagio in Fall 2008. That meeting had been organized to allow participants to explore the emerging field of synthetic biology and frame the issues and scope of the forthcoming 2009 Symposium. The Bellagio meeting also provided insight into the operations and interests of the three convening organizations (NAS, Royal Society, and OECD), allowing each organization to collaborate more successfully, and to avoid duplication of efforts.

The 2008 Bellagio meeting and subsequent 2009 International Symposium, led the National Academy of Sciences and Engineering to collaborate with The Royal Society, Royal Academy of Engineering, Chinese Academy of Sciences, and Chinese Academy of Engineering, in organizing symposia in each country during 2011-2012. For a report of those discussions see: http://sites.nationalacademies.org/PGA/stl/synthetic_biology/index.htm.

Moreover, the Bellagio discussions led to the establishment of the National Academies' Forum on Synthetic Biology (http://sites.nationalacademies.org/pga/stl/SynBio_Forum/index.htm), which continues both international and domestic dialogues on synthetic biology. An international community of scholars, policymakers and industrialists in synthetic biology are tied to 2008 Bellagio meeting.

(Information provided by Juanita Frazier-Martin, Bellagio Programs, The Rockefeller Foundation)

1.2 Opportunities and Challenges in the Emerging Field of Synthetic Biology: A Symposium

On July 9-10, 2009, under the auspices of the National Academies (CSTL, BLS, STEP, and NAE), the Organization for Economic Cooperation and Development (OECD), and the Royal Society, an international symposium was held in Washington, DC to bring together the scientific, engineering, legal, and policy communities along with members of the public to explore the opportunities and challenges posed by the emerging field of synthetic biology. The symposium featured invited presentations and discussions on the myriad of legal, policy, and ethical questions that synthetic biology raises in the global enterprise.

The overarching goals of the meeting were to help foster this new community of professionals, to frame the language of the discussion and the issues, to identify issues and areas for future study, and to educate the public and policy-makers about this emerging field.

The OECD and the Royal Society issued a report on the symposium in May 2010 (http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_056989.pdf).

Support for the Symposium was provided by the National Science Foundation, Sloan Foundation, and Biotechnology Industry Organization.

A planning meeting was held on October 22-25, 2008 at the Rockefeller Foundation's Bellagio Center in Bellagio, Italy. (View Planning Meeting Agenda)

1.3 Synthetic Biology and Conservation

Clare College, Cambridge, UK
April 9-11, 2013

See background document: *How will synthetic biology and conservation shape the future of nature? A Framing Paper*. March 2013. Kent Redford ed. Wildlife Conservation Society. 1-30. https://secure3.convio.net/wcs/pdf/Synthetic_Biology_and_Conservation_Framing_Paper.pdf

1.4 New Genomic Solutions for Conservation Problems

Sausalito, CA, USA
April 6-9, 2015

http://longnow.org/revive/about-the-workshop-sb/
http://longnow.org/revive/meeting-report/

2. Background reading

2.1 IUCN SSC Guiding Principles on De-extinction for Conservation Benefit

2.2 Kent H Redford, William Adams, and Georgina Mace. 2013. *Synthetic Biology and Conservation of Nature: Wicked Problems and Wicked Solutions*. PLoS Biol 11(4): e1001530. doi:10.1371/journal.pbio.1001530

2.3 Jeantine Lunshof. 2015. *Regulate gene editing in wild animals*. Nature (521): 127. doi:10.1038/521127a

2.4 Steven A. Benner and Michael Sismour. 2005. *Synthetic Biology*. Nature Reviews: Genetics (6): 533-543. doi:10.1038/nrg1637

2.5 Report of the Ad Hoc Technical Expert Group on Synthetic Biology. 2015. Convention on Biological Diversity. https://www.cbd.int/doc/decisions/cop-12/cop-12-dec-24-en.pdf

2.6 *How will synthetic biology and conservation shape the future of nature? A Framing Paper*. March 2013. Kent Redford ed. Wildlife Conservation Society. 1-30. https://secure3.convio.net/wcs/pdf/Synthetic_Biology_and_Conservation_Framing_Paper.pdf

2.7 Winter, G. 2015. *The Regulation of Synthetic Biology by EU Law: Current State and Prospects*. In: Bernd Giese, Christian Pade, Henning Wigger , Arnim von Gleich (eds.), Synthetic Biology - Character and Impact, Springer, Heidelberg. 213-234. http://link.springer.com/chapter/10.1007/978-3-319-02783-8_11

3. Other

3.1. CBD´s ad hoc Technical Expert Group on Synthetic Biology and online forum: https://bch.cbd.int/synbio