ATTACHMENT B. Annual Project Report Form (Revised 11.21.19)

1. Project Number:

19120114-I

2. Project Title:

Long-term Monitoring of Oceanographic Conditions in the Alaska Coastal Current from Hydrographic Station GAK1

3. Principal Investigator(s) Names:

Seth L. Danielson and Thomas J. Weingartner, University of Alaska Fairbanks

4. Time Period Covered by the Report:

February 1, 2019-January 31, 2020

5. Date of Report:

March 2020

6. Project Website (if applicable):

www.gulfwatchalaska.org

http://research.cfos.uaf.edu/gak1/

https://portal.aoos.org/gulf-of-alaska#metadata/3c4ecb88-6436-4312-8281-ed584e020b0e/project

7. Summary of Work Performed:

The project sampling objectives were accomplished with conductivity and temperature at depth (CTDs) in most months and a successful annual recovery and re-deployment of the GAK1 mooring in March 2019. Nominally monthly CTD casts were done from *M/V Dora*, *M/V Acorn*, *R/V Nanuq*, and *R/V Sikuliaq*. We took delivery of *R/V Nanuq* in July 2019 and Danielson then took her out on a maiden cruise to Prince William Sound and the Copper River Plume region over 10 days in July-August. GAK1 is the "home tenant" user for *R/V Nanuq*, and we have a standing reservation for one trip in the first week of each month for the GAK1 sampling.

The time series data from the recovered 2018-2019 mooring (Fig. 1) were generally of high quality. We observed large-magnitude freshening in the near-surface sensor in August 2018, a relaxation into late September, and then additional freshening into November.

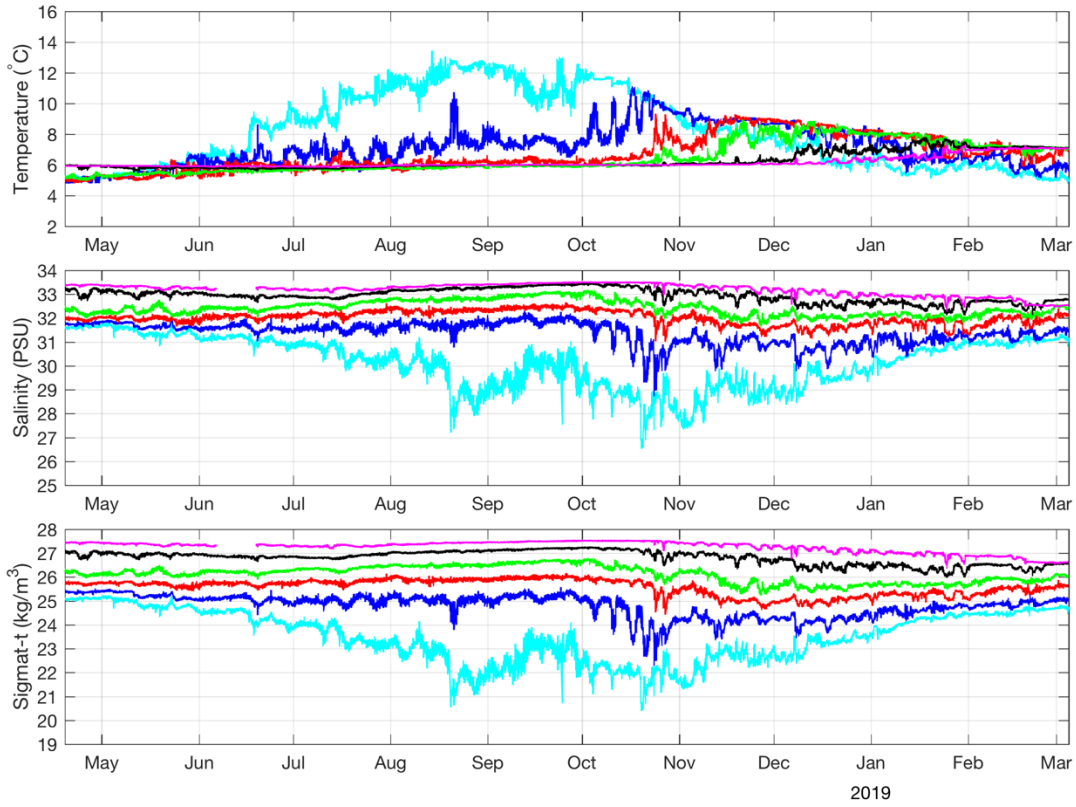

Figure 1. Time series of the 2018-2019 GAK1 mooring records. Colors denote the nominal depth of each instrument from shallow (cyan, 20 m) to deep (magenta, 250 m).

On the analytical side, significant findings by the Gulf Watch Alaska synthesis report on temperature by Danielson et al. (2019) include:

- Large-scale modes of climate variability explain only a modest fraction of coastal Gulf of Alaska thermal anomalies.
- Satellite measures of sea surface temperature (SST) miss 30-40% of the daily anomaly at GAK1.
- Fidelity of satellite-based measures of SST vary spatially, with better performance offshore and degraded performance nearshore in regions of complex bathymetry (e.g., southeast Alaska archipelago, Prince William Sound).

- Co-variability of SST depends on frequency band of interest and on separation distance between any two stations. Hence, the value of GAK1 as a proxy for other sites depends on time scale of interest and distance.
- GAK1 is well representative of a dominant portion of the whole northern Gulf of Alaska shelf, as shown in Fig. 2.
- SST is not a strong predictor for near-bottom temperatures at four representative long-term monitoring CTD sites in the coastal Gulf of Alaska (Kachemak Bay KB6, GAK1, Prince William Sound KIP2 and Glacier Bay GLBA20). This is shown in Fig. 3.
- GAK1 SST is inversely correlated with near-bottom temperatures at the shelf break.
- The Pacific marine heatwave set up with anomalous air-sea heat flux in 2013. Heating continued over the northern shelf through 2014 and 2015.
- The majority of heat in the 250-m water column at GAK1 is carried by oceanic advection rather than local heating through the surface. Hence, near-bottom warming is delayed relative to heating at the surface.
- During the 2014-2016 Pacific marine heatwave, far offshore waters warmed most rapidly and then cooled beginning in early 2014, while nearshore waters warmed more slowly and with fairly tight synchrony through 2014, cooled in early 2015 and then warmed again through 2016.

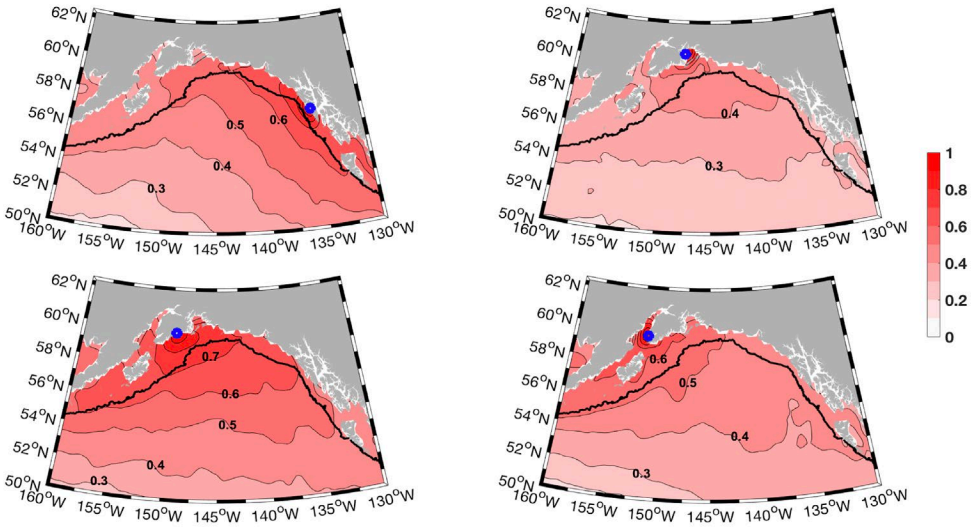

Figure 2. Correlation of the optimum interpolation seas surface temperature (SST) daily SST anomaly relative to reference points (blue circles) at Sitka (upper left), western Prince William Sound (upper right), GAK1 (lower left) and system-wide monitoring program (lower right). The continental slope is denoted with a thick black contour at the 1000 m depth level.

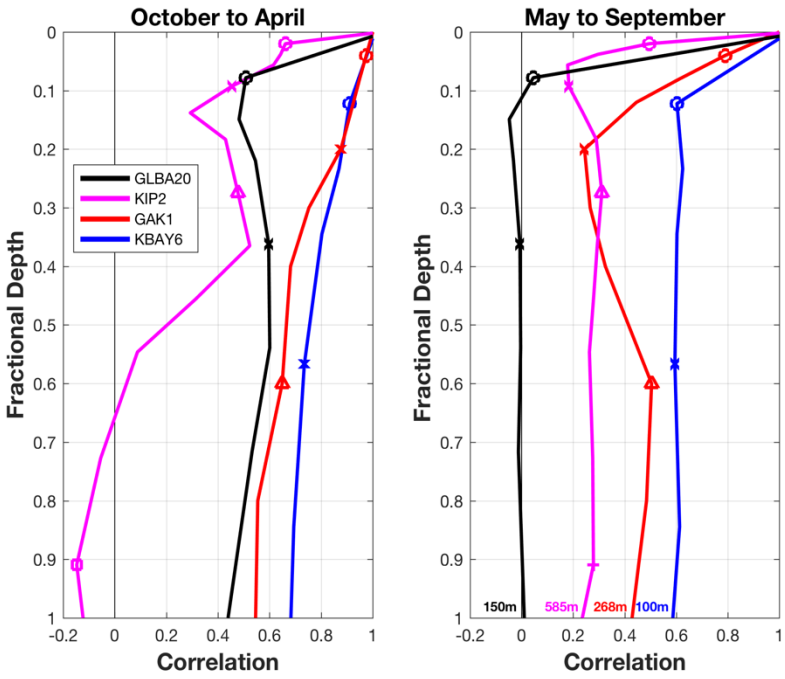

Figure 3. Correlation between temperature anomalies at the surface and temperature anomalies at standard depths (0, 10, 20, 30, 50, 75, 100, 150, 200, 250, 300, 400, 500 and 550 m) for winter (left) and summer (right) season as resolved by CTDs taken at stations GLBA20 (black), KIP2 (magenta), GAK1 (red) and the mid-transect station T09-06 in Kachemak Bay (blue). Symbols o, Δ, x and + show the location of the 10, 50, 150 and 500 m depth levels, respectively. The seafloor depth of each station is noted at the bottom of the right-hand panel.

8. Coordination/Collaboration:

A. Long-term Monitoring and Research Program Projects

1. Within the Program

GAK1 provides a coastal long-term context for the Gulf Watch Alaska program as a whole. The recent Gulf Watch Alaska temperature analysis synthesis report (Danielson et al. 2019) shows that the GAK1 site is ideally located for being a reference point. The Gulf Watch Alaska framework for integration with other principal investigators and components of the environmental drivers monitoring, and Herring Research and Monitoring are outlined separately in the project management proposals.

EVOSTC funding to the Seward Line project (principal investigator [PI] Hopcroft, project 19120114-L) is allowing the collection and processing of discrete nutrient, chlorophyll and zooplankton samples at GAK1. We provide the GAK1 survey vessel as a platform-of-opportunity to Hopcroft's GAK1 sampling and have now assembled an annual cycle of this multi-disciplinary sampling. When possible, we leverage the occupation of GAK1 by Long Term Ecological Research (LTER) and Gulf Watch Alaska Seward Line cruises. In this past, this occurred in spring and fall year and now this occurs in summer as well.

PI Danielson worked with the Nearshore component (PI Monson, project 19120114-H) on the synthesis chapter on temperature variation (Danielson et al. 2019) and contributed data to the chapter on ecosystem response to the marine heatwave (Suryan et al. 2019). Danielson has also been working on compiling other environmental time series data that may be useful in analysis

and interpretation of other Gulf Watch Alaska observations. Such datasets include sea surface height anomalies and geostrophic velocity vectors derived from ocean altimeter satellites.

2. Across Programs

a. Herring Research and Monitoring

The Herring Research and Monitoring program tagging project (PI Bishop, project 1916011-B) provided a POST array acoustic tag recorder for deployment on the GAK1 mooring. The first recovery of this instrument will take place in March 2020 and a replacement instrument will be deployed at this time.

b. Data Management

Danielson is working with Axiom data managers to generate data visualizations and that can be shared via the Alaska Ocean Observing System data portals and other internet web pages. One such example using GAK1 data can be found at: https://researchworkspace.com/file/2656970/anomaly-plot-gak1-mooring.ipynb. Another example is the development of a real-time ship tracking interface that could provide up-to-the-hour ship-to-shore data transfers while the Seward Line cruise is in the field on *R/V Sikuliaq*. This functionality would assist adaptive sampling techniques, by forming tighter linkages between the field crew and shoreside support. For example, based on the real-time data feed, on-shore analysts could download, compress, and deliver to the field crew remotely-sensed data that may be useful in directing the fieldwork. This work is ongoing.

B. Individual Projects

The GAK1 project collaborates with the Ocean Acidification Research Lab (OARC) to help facilitate the GAK-OA buoy turnaround. This mooring is located close to GAK1, in Sunny Cove.

C. With Trustee or Management Agencies

We contribute indicators to the National Oceanic and Atmospheric Administration's (NOAA's) Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council for 2019 (Zador et al. 2019, https://access.afsc.noaa.gov/REFM/REEM/ecoweb/index.php): 1) GAK1 near surface and near seafloor salinity and temperature, 1970–2019 and 2) GAK1 monthly anomaly time series for the 1970–2019. In addition, as a dataset with a 50-year time series that is publicly available, GAK1 data are used for a wide variety of research and management purposes.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed Publications

The publications below use GAK1 data:

Coyle, K.O., A.J. Hermann, and R.R. Hopcroft. 2019. Modeled spatial-temporal distribution of productivity, chlorophyll, iron and nitrate on the northern Gulf of Alaska shelf relative to field observations. Deep-Sea Res II 165:163-191.

Doyle, M.J., S.L. Strom, K.O. Coyle, A.J. Hermann, C. Ladd, A.C. Matarese, S.K. Shotwell, and R.R. Hopcroft. 2019. Early life history phenology among Gulf of Alaska fish species: Strategies, synchronies, and sensitivities. Deep-Sea Res II 165:41-73.

Laurel, B.J., and L.A. Rogers. 2020. Loss of spawning habitat and prerecruits of Pacific cod during a Gulf of Alaska heatwave. Canadian Journal of Fisheries and Aquatic Sciences 999:1-7.

Nielsen, J.M., L.A. Rogers, D.G. Kimmel, A.L. Deary, and J.T. Duffy-Anderson. 2019. Contribution of walleye pollock eggs to the Gulf of Alaska food web in spring. Marine Ecology Progress Series 632:1-12.

Roncalli, V., M.C. Cieslak, M. Germano, R.R. Hopcroft, and P.H. Lenz. 2019. Regional heterogeneity impacts gene expression in the subarctic zooplankter *Neocalanus flemingeri* in the northern Gulf of Alaska. Communications Biology 2:1-13.

Sánchez-Montes, M.L., E.L. McClymont, J.M. Lloyd, J. Müller, E.A. Cowan, C. Zorzi, and A. de Vernal. 2020. Late Pliocene Cordilleran Ice Sheet development with warm Northeast Pacific sea surface temperatures. Climate of the Past 16:299-313.

2. Reports

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. 2019. Chapter 1 A study of marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, AK.

Danielson, S.L, and T.J. Weingartner. 2019. Long-term Monitoring of Oceanographic Conditions in the Alaska Coastal Current from Hydrographic Station GAK1. FY18 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 17120114-I. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, AK.

Suryan, R.M., M. Arimitsu, H. Coletti, R.R. Hopcroft, M.R. Lindeberg, S. Batten, M.A. Bishop, R. Brenner, R. Campbell, D. Cushing, S. Danielson, D. Esler, T. Gelatt, S. Hatch, S. Haught, K. Holderied, K. Iken, D. Irons, D. Kimmel, B. Konar, K. Kuletz, B. Laurel, J.M. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, S. Pegau, J. Piatt, L. Rogers, A. Schaefer, J. Straley, K. Sweeney, M. Szymkowiak, B. Weitzman, J.

Bodkin, and S. Zador. 2019. Chapter 4 Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, AK.

Danielson S. 2019. Oceanographic station GAK1 water column properties. *In* Zador, S., E. Yasumiishi, and G.A. Whitehouse, G.A. (editors). 2019, Ecosystem Status Report 2019. North Pacific Fishery Management Council. https://access.afsc.noaa.gov/REFM/REEM/ecoweb/pdf/2019GOAecosys.pdf

3. Popular articles

Danielson, S., R. Hopcroft, K. Holderied, and R. Campbell. 2019. Tracking water layers in the ocean. PWSSC Delta Sound Connections (https://pwssc.org/wp-content/uploads/2019/05/DSC-2019_WEB.pdf).

B. Dates and Locations of any Conference or Workshop Presentations where EVOSTC-funded Work was Presented

1. Conferences and Workshops

Brydie, A., and S. Danielson. 2019. Copper River Plume. LTER REU Mini-Symposium, August.

Danielson, S. 2019. Changing stratification over Alaska region continental shelves suggests altered diapycnal mixing and nutrient fluxes, Invited Talk, 3rd International Symposium "Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem", University of Tokyo, May.

Danielson, S. 2019. 21st Century Oceanography in the Last Frontier, Invited Keynote Presentation, RVTEC, Fairbanks, AK, November.

Danielson, S. 2019. Presentation to the Alaska Ocean Observing System Board, Anchorage, AK, December.

Danielson, S. 2020. presentation to the Northern Gulf of Alaska Long Term Ecological Research Program PI meeting, January.

2. Public presentations

Danielson, S. 2019, Assessing recent changes in Alaska region oceanic heat content, Osher Lifelong Learning Institute, Fairbanks, AK, October.

C. Data and/or Information Products Developed During the Reporting Period, if Applicable

We continue to update annual metrics of Gulf of Alaska thermal and haline trends for the NOAA Ecosystem Status Report (Zador et al. 2019).

D. Data Sets and Associated Metadata that have been Uploaded to the Program's Data Portal

GAK1 hydrographic profile and mooring data have been uploaded to the Research Workspace (https://workspace.aoos.org/project/23194/files).

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comment (FY19): *Science Panel is interested in understanding better how the LTER program is integrated with the GAK1, Seward line and nearshore monitoring, specifically activities and monitoring.*

PI Response (FY19): GAK1 provides the year-round "anchor" for coastal Gulf of Alaska full water column measurements. A number of studies have highlighted the importance of winter month processes in setting habitat conditions in the Gulf of Alaska, specifically in whether or not the system finds itself in marine heatwave conditions (e.g., Bond et al. 2015). Seward Line cruises occur in spring, summer and fall so the GAK1 observations provide our only *in-situ* measurements year-round on the inner Gulf of Alaska shelf. Hence, the LTER program greatly benefits from the GAK1 program's year-round presence. GAK1 benefits from the LTER program through the extremely wide suite of measurements that are made at the GAK1 site on each LTER cruise. The LTER program puts the local-scale GAK1 suite of measurements into a much fuller ecological context. Such measurements include primary productivity, carbon cycling and export, iron speciation, marine mammal and bird observations, and others. The LTER program also contributes some funding for students, so we expect an even greater use of the GAK1 data to result.

Please also see nearshore ecosystems (19120114-H, Coletti et al.) and Seward Line (19120114-L, Hopcroft) projects for additional responses to this comment.

11. Budget:

Please see provided program workbook. In order to take advantage of the M.J. Murdock Charitable Trust matching funds, we postponed spending 2017 equipment funds until 2018. Though not shown

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$47.1	$48.2	$49.3	$50.4	$51.6	$246.6	$114.0
Travel	$4.4	$4.4	$4.4	$4.4	$4.4	$21.9	$11.0
Contractual	$18.7	$18.7	$18.7	$18.7	$18.7	$93.3	$52.0
Commodities	$6.1	$6.1	$6.1	$6.1	$6.1	$30.5	$11.0
Equipment	$39.3	$39.5	$23.7	$15.8	$16.0	$134.3	$73.0
Indirect Costs (*25% of non-equip.*)	$19.1	$19.3	$19.6	$19.9	$20.2	$98.1	$34.0
SUBTOTAL	$134.6	$136.2	$121.7	$115.2	$116.8	$624.6	$295.0
General Administration (9% of	$12.1	$12.3	$11.0	$10.4	$10.5	$56.2	N/A
PROJECT TOTAL	$146.8	$148.4	$132.6	$125.6	$127.4	$680.8	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

in this breakdown, PI Danielson's transition from Research Faculty to Tenure Track Faculty status will allow him to re-allocate some of his salary into student and staff support over FY19-FY21.

LITERATURE CITED

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. 2019. Chapter 1 A study of marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. *In* M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Suryan, R.M., M. Arimitsu, H. Coletti, R.R. Hopcroft, M.R. Lindeberg, S. Batten, M.A. Bishop, R. Brenner, R. Campbell, D. Cushing, S. Danielson, D. Esler, T. Gelatt, S. Hatch, S. Haught, K. Holderied, K. Iken, D. Irons, D. Kimmel, B. Konar, K. Kuletz, B. Laurel, J.M. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, S. Pegau, J. Piatt, L. Rogers, A. Schaefer, J. Straley, K. Sweeney, M. Szymkowiak, B. Weitzman, J. Bodkin, and S. Zador. 2019. Chapter 4 Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, AK.

Zador, S., E. Yasumiishi, and G.A. Whitehouse, G.A. (editors). 2019. Ecosystem Status Report 2019. North Pacific Fishery Management Council. https://access.afsc.noaa.gov/REFM/REEM/ecoweb/pdf/2019GOAecosys.pdf