Interagency Ecological Program:

GUIDING FRAMEWORK FOR CONDUCTING IEP

SYNTHESIS WORK

Interagency Ecological Program

COOPERATIVE ECOLOGICAL INVESTIGATIONS SINCE 1970

Science, Synthesis, Service

How to Use this Document

This document is meant to provide definition of the charge and target products for synthesis work led by IEP agency staff. It also defines the role of dedicated IEP synthesis staff and the processes by which new synthesis work is identified. **This is not a governance document for IEP**, but rather a “touchstone” framework to clarify the purpose and goals of IEP synthesis work, and underlying processes

What Is Scientific Synthesis and What is its Place in IEP?

The word "synthesis" refers to the combination of separate components to form a whole. Scientific synthesis is the integration of existing, diverse datasets and knowledge to produce new insights or knowledge (Carpenter et al. 2009, Hampton and Parker 2011).

"Synthesis occurs when disparate data, concepts, or theories are integrated in ways that yield new knowledge, insights, or explanations. "

"Accelerate Synthesis in Ecology and Environmental Sciences" Carpenter et al. 2009. *BioScience* 59: 699-701.

Ecology has played a leadership role in synthesis, because ecological work is intrinsically about connections and interactions between species and their environment, and this type of investigation calls on datasets of many types. Synthesis can be conducted by a single individual, or by teams ranging in size from a few people to large, interdisciplinary and multi-affiliation groups. Much of the recent progress in the general field of ecological synthesis has progressed because of formalized synthesis centers and groups. Over the past two decades, nine major ecological synthesis centers have developed across Europe and the United States (Baron et al. 2017). These dedicated nodes of scientific synthesis bring together experts, facilitate intensive face-to-face workshops focused on rapid production of analyses and reports, support data management and integration of datasets, and provide focused time for thinking, analysis, and writing (Carpenter et al. 2009, Hampton et al. 2015, Baron et al. 2017). Often these efforts tackle difficult, seemingly intractable applied problems and questions, whose resolution would provide substantial societal benefits. For example, synthesis of large volumes of data on ocean environmental conditions has resulted in development of an independent, global Ocean Health Index. This index provides policy makers with a clear and unbiased assessment of the ocean conditions they are charged with managing (Halpern et al. 2012). **Having groups of scientists dedicated to the synthesis of available data is beneficial because they provide narratives and analyses that distill volumes of data and information into the most salient points for a given question.**

"Since 1995, a structured approach to the inter-, multi-, and trans- disciplinary collaboration around big science questions has been supported through synthesis centers around the world. These centers are finding an expanding role due to ever-accumulating data and the need for more and better approaches to solve real-world problems."

"Transdisciplinary synthesis for ecosystem science, policy, and management: The Australian experience" (Lynch et. al. 2015) Science of The Total Environment 534: 173-184

One example of a dedicated synthesis group is the National Center for Ecological Analysis and Synthesis (NCEAS website), which formed in 1995. The start of NCEAS was motivated by an increasing condition of "scattered data" in the general field of ecology, concurrent with increasing demand for science-based information for management of complex problems facing society and the planet.

The Interagency Ecological Program (IEP) is a collaborative and multi-agency group that has produced ecological data for the San Francisco Estuary (SFE) since 1970. IEP conducts ecological synthesis to perform analyses required for environmental mandates, adaptive management of those mandates, and to enhance the general understanding of SFE system ecology. Mirroring the broad trend in the ecology field toward enhanced synthesis in response to growing data and information volumes, IEP has worked to increase its own internal capacity for synthesizing data and information for the SFE. Since 2013, five scientist positions among three agencies have been added or redirected for dedication to synthesis work.

This document focuses on charges for these dedicated synthesis positions within IEP and the processes through which their specific work is developed. Key acknowledgements here are as follows: (1) IEP synthesis work has been ongoing and precedes the introduction of dedicated staff for the effort; (2) the volume of synthesis work to be done for IEP exceeds what is feasible for the five dedicated synthesis positions and therefore these individuals necessarily work in teams that include various scientific staff across agencies; and finally (3) synthesis work may be led by scientists that are not part of the dedicated synthesis positions. In order to ensure efficient coordination, ideally synthesis efforts led by staff that are not part of the five dedicated synthesis positions are coordinated within IEP by including them in the Annual IEP Work plan or otherwise communicating their objectives and results (e.g. with the IEP Science Management Team or appropriate IEP Project Work Teams).

What is the Charge of IEP Synthesis Work?

Ecological synthesis is a major component of the IEP mission:

> "The mission of the IEP is to provide and integrate relevant and timely ecological information for management of the Bay-Delta ecosystem and the water that flows through it. This is accomplished through collaborative and scientifically sound monitoring, research, modeling, and synthesis efforts for various aspects of the ecosystem."
>
> -Interagency Ecological Program Strategic Plan, 2014.

Synthesis is fundamental to the mission of IEP for the same reason that synthesis has been a growing focus for ecological research in general: it is not possible or reasonable to address complex environmental and societal issues by examining one dataset at a time. In addition, IEP faces the sameinformation and "data deluge" (Baraniuk 2011) that scientists across many disciplines face in this day and age: data are often produced faster than the rate of analysis or even data management. Synthesis work within IEP addresses these needs for simultaneous analysis of multiple datasets, efficient management of data to facilitate synthetic analyses, and the clear communication of the outcomes of synthesis work ("take-home messages").

The charge of IEP Synthesis work is to facilitate and contribute to the management, transparency, integration, and analysis of the temporally and topically vast ecological datasets collected in the SFE. A related charge is to communicate the information gained from synthesis efforts to managers, other scientists, and the interested public. This general charge can be divided into four basic categories of activities (Box 1): 1) Conduct management-relevant analysis and synthesis of ecological datasets, 2) Facilitate open science practices, 3) Integrate monitoring datasets, and 4) Distill IEP Science findings into cohesive narratives. Major products of the IEP Synthesis work are aligned with these categories (Table 1).

Box 1. Charges for IEP Synthesis

1. **Conduct management-relevant analysis and synthesis of ecological datasets, employing predictive modeling as appropriate.** This charge includes rigorous and defensible analyses of multiple datasets to address major management needs, facilitate adaptive management, and enhance our understanding of SFE ecology. This charge may include predictive modeling to forecast effects of management actions or climate scenarios. These analyses include those required to adaptively manage environmental mandates. This work may also include development of conceptual models.
2. **Implement open science practices** to achieve a high level of transparency for IEP data and analyses, in keeping with contemporary Open Science practices (Hampton et al. 2015). Adoption of open science practices facilitates effective communication and data sharing among IEP scientists and partners, as well as rapid data exploration and synthesis.
3. **Integrate monitoring datasets** such that multiple datasets with common parameters can be used together. Develop recommendations for consistent field and lab practices across surveys, while maintaining the integrity of long-term datasets.
4. **Distill IEP Science findings into cohesive narratives** that are accessible and clear to targeted audiences, such as resource managers, policy makers, scientists from diverse fields, or the interested public.

IEP synthesis uses data from the long-term monitoring programs, focused studies, and modeling work conducted within IEP and generally within the SFE. Within the IEP, there are over 15 discrete monitoring programs that have been in place since at least the early 2000s, with several of these now spanning five decades. These monitoring programs have a wide breadth, sampling ecosystem aspects ranging from nutrients to sturgeon. In addition, IEP operates a network of high-frequency water quality sensors, comprising over 150 stations in the Delta and Suisun region. Each year, the IEP work plan includes the long-term monitoring programs, and targeted studies that focusing species or system ecology, or development of new tools for monitoring. Many of these studies result in peer-reviewed publications, with a rate exceeding 50 articles per year in some years.

“The ‘burden of knowledge’ … embedded in increasing numbers of journals, papers, and books requires synthesis, if problem-solvers are to use that mass of information efficiently.”

“Accelerate Synthesis in Ecology and Environmental Sciences” Carpenter et al. 2009. *BioScience* 59: 699-701.

IEP synthesis focuses its topics on management-relevant questions that leverage the IEP survey data. For example, IEP Synthesis has addressed topics specific to the Biological Opinions for protected species, such as effects of enhanced Delta outflow in the fall on Delta Smelt habitat (Brown et al. 2014). Development of a life cycle model for Delta Smelt (Mitchell et al. 2017, Polansky et al. 2018a, Polansky et al. 2018b) based on a host of IEP survey data has allowed for abundance estimates. This information has been crucial to management of incidental take during IEP monitoring and research. In other examples, the 2015 synthesis of Delta Smelt Biology (IEP-MAST 2015) and the Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL, Johnson et al. 2017) resulted in updated available information on the focal species and developing conceptual models for environmental drivers behind species population dynamics. These conceptual models are the bases for the Delta Smelt Resiliency Strategy and the Sacramento Valley Salmon Resiliency Strategy (California Natural Resources Agency in 2016 and 2017, respectively). These documents provide science-based recommendations for management actions that are likely to address the drivers of population decline. Since 2017, some of the actions from the Resiliency Strategies have seen at least pilot implementation, and in some cases, have demonstrated habitat improvements. These are examples of management actions that are originally grounded in IEP synthesis.

The IEP synthesis efforts can also be leveraged to improve monitoring networks within IEP. For example, the SAIL assessed the monitoring networks for Winter-run Chinook Salmon and Green and White Sturgeon, and developed recommendations for the enhancement of these networks (Heublein et al. 2017, Johnson et al. 2017). These recommendations, if adopted, will provide enable agencies to make more informed decisions for effectively meeting compliance objectives.

In general, IEP synthesis products can be categorized into the charges that are outlined above (Box 1). Brief descriptions and examples of products for each charge are listed in Table 1.

Table 1 Examples of the types of IEP synthesis products, categorized by the basic charge, goal, and audience. The products listed for each charge are not an exhaustive list, but rather a set of examples**.**

Charge	Goal	Type of Product	Audience	Example Product
Synthesis and Analysis of Multiple Ecological Datasets	Enhanced understanding of SFE ecology; Evaluate pilot management; Facilitate adaptive management actions	Peer-Reviewed Articles, Technical Reports, Conference Presentations	General Scientific Community, IEP Managers	(Sommer et al. 2007, Cloern et al. 2010, Mac Nally et al. 2010, Thomson et al. 2010, Brown et al. 2014)
Integration and Evaluation of Monitoring Datasets	Integration and evaluation of IEP datasets with shared parameters; recommendations for improved monitoring networks to address management needs	Technical Reports, Peer- reviewed publications	IEP Science Managers	Salmon and Sturgeon Assessment of Indicators by Life Stage (Heublein et al. 2017, Johnson et al. 2017) Delta Smelt Life Cycle Model
Integration and Evaluation of Monitoring Datasets	Integration and evaluation of IEP datasets with shared parameters; recommendations for improved monitoring networks to address management needs	Integrated datasets derived from multiple monitoring programs	IEP Data Users	Salmon and Sturgeon Assessment of Indicators by Life Stage (Heublein et al. 2017, Johnson et al. 2017) Delta Smelt Life Cycle Model
Facilitation of Open Science Practices for IEP	Transparency of IEP data and analyses	Technical Working Groups, Publication of analyses and code for IEP products, Digital Object Identifiers (DOIs)	IEP Scientists, Potential and Current Collaborators, Stakeholders, Interested Public	Data Utilization Working Group (DUWG), DOI for the DWR Yolo Bypass Fish Monitoring Program and the USFWS Delta Juvenile Fish Monitoring Program on the Environmental Data Initiative
Facilitation of Open Science Practices for IEP	Documentation of IEP metadata	Code for deriving datasets or data analyses	IEP Scientists, Potential and Current Collaborators, Stakeholders, Interested Public	Data Utilization Working Group (DUWG), DOI for the DWR Yolo Bypass Fish Monitoring Program and the USFWS Delta Juvenile Fish Monitoring Program on the Environmental Data Initiative
Facilitation of Open Science Practices for IEP	Broad "citability" of IEP data	Code for deriving datasets or data analyses	IEP Scientists, Potential and Current Collaborators, Stakeholders,	IEP Open Synthesis GitHub website

Charge	Goal	Type of Product	Audience	Example Product
			Interested Public	
Distillation of Science and Synthesis Findings	Communicate IEP science and synthesis findings	Fact Sheets	Managers, General Scientific Community, Interested Public	Various fact sheets
Distillation of Science and Synthesis Findings	Communicate IEP science and synthesis findings	Oral or Poster Presentations	Managers, General Scientific Community, Interested Public	Presentations at IEP Director Meetings
Distillation of Science and Synthesis Findings	Communicate IEP science and synthesis findings	Oral briefings for IEP Director or other manager	Managers, General Scientific Community, Interested Public	Synthetic IEP Status and Trends reports highlighting multiple datasets, published online quarterly

How Does IEP Choose Synthesis Topics?

The scope of potential synthesis topics under the IEP mission of producing management-relevant information is broad (e.g., ecological responses to flow actions, climate change, habitat restoration). Given that synthesis resources are limited in IEP, the choice of topic must be considered carefully with respect to relevance and suitability for available staff resources.

Synthesis topics are developed, supported, and informed by IEP PWTs and agency scientists ("bottom-up" initiatives) and by directives from agency directors ("top-down" initiatives). Examples of "top-down" projects include the SAIL effort for Winter-run Chinook Salmon and sturgeon monitoring network evaluation, and the Flow Alteration Management, Analysis, and Synthesis Team (FLOAT MAST) to evaluate ecosystem effects of wet conditions in 2017. The latter effort was responsive to a federal mandate (2008 USFWS Delta Smelt Biological Opinion) to evaluate outcomes of required outflow enhancements to Delta Smelt habitat. Examples of "bottom-up" projects include evaluation of changes in drought resilience within Delta fish communities over time, and utilization of multiple fisheries datasets to examine evidence for shifts in habitat distribution for selected species over time (Mahardja et al., 2017, Sommer et al. 2011).

The IEP Lead Scientist, Synthesis Team Lead (DWR, Program Manager II), and other synthesis staff coordinate with PWT leads, the IEP Science Management Team (SMT), Coordinator Team (CT), and Directors to identify synthesis needs. Some of this communication happens within the routine meeting schedule of IEP (monthly SMT and CT meetings, quarterly Director Team meetings). On a quarterly basis, the core staff for IEP synthesis, lead individuals for IEP synthesis projects, the IEP Lead Scientist, and interested CT and SMT members meet to share progress updates on each ongoing project, identify team needs and discuss emerging synthesis topics. These quarterly meetings allow for focused dialogue between managers and synthesis staff. These meetings are also meant to identify and coordinate staff time commitments across multiple projects.

In addition to input from managers and directors, IEP Synthesis work needs fresh ideas and knowledge from scientists representing broad affiliations and expertise. To receive this input, the IEP Lead Scientist, Science Management Team, and Coordinator Team solicit ideas from IEP's 18 PWTs and the IEP Stakeholder Group, which are open for scientific exchange on various areas of ecology in the SFE. The topics suggested by PWTs for synthesis should meet the following criteria:

1. The topic has been the subject of substantial focused research or monitoring (i.e., there are data and other materials available for synthesis);
2. The topic is timely and relevant to management;
3. Informed scientists are available to participate the synthesis effort.

There are numerous examples of synthesis efforts that have been inspired and even conducted within PWT groups or simply conversations among IEP scientists. Perhaps the largest example of a major synthesis effort generated and conducted within a PWT is the development of a suite of conceptual models describing the most recent knowledge of tidal wetland ecology (Sherman et al. 2017). These conceptual models now inform the hypotheses and approaches used to evaluate effects of tidal wetland restoration in the Delta and Suisun regions.

To the greatest extent possible, IEP Synthesis efforts (especially those that involve staff dedicated to IEP Synthesis) are included in the Annual IEP Work Plan. Thus, as with any Work Plan “Directed Study” element, a proposal for the work is developed and reviewed through the IEP Work Planning process (Table 2). Any IEP scientist or manager may participate in the work planning process, as long as the work and resources are already available and can be committed to the effort. By including synthesis projects in the IEP Work Planning process, IEP synthesis efforts are transparent and visible, and are also vetted by experts within the SFE scientific community. Quarterly coordination meetings of the IEP Synthesis team (Table 2) are integrated into the work planning schedule for directed studies to promote the necessary coordination and input from both PWTs and agency managers and directors for development of new synthesis topics.

However, the degree of review for individual synthesis projects will vary substantially depending on the scale of the project. While there will be high profile synthesis projects conducted by larger teams (e.g., SAIL, FLOAT MAST), IEP also encourages individual scientists to synthesize data. For example, it is common for lead scientists of monitoring surveys to periodically do synthetic work to summarize their own projects (e.g. Feyrer et al. 2006; Takata et al. 2017). Much of this work is included and expected as part of the regular activities of these monitoring projects, and therefore may not necessarily require a new study element in the IEP Work Plan. Similarly, it is common for IEP scientists to conduct synthesis work with previously studied IEP datasets under a new study objective (e.g. Goertler et al. 2017; Mahardja et al. 2017). This type of small group technical work is encouraged to increase our overall knowledge of the system.

For this reason, and because IEP scientists and collaborators are free to take on synthesis projects as their availability and interest allows, some IEP synthesis efforts may not be included in the Annual Workplan. IEP welcomes these efforts that occur outside of the IEP Annual Work Plan or formal IEP teams and hopes that the scientists leading these efforts share their findings in the interest of broadening the collective understanding of SFE ecology.

Table 2. General annual schedule for the IEP Synthesis team for developing new synthesis topics and coordinating ongoing projects. Light blue boxes indicate synthesis team activities. Synthesis team coordination activities include core staff for IEP Synthesis, leads of all current synthesis projects, and interested members of the CT and SMT. Dark blue boxes indicate milestones of the IEP Annual Workplan planning process for new directed studies, which may or may not be synthesis projects.

IEP Synthesis Team: Annual Schedule of Planning Tasks and Coordination Activities	
January	
February	
March	IEP Program Manager distributes **call for new directed studies** to SMT, CT, and PWT Chairs.
March	**Synthesis Team Coordination Meeting:** Current project updates, identify emerging needs for synthesis identified by IEP agency managers, SMT, and PWT members. Identify leads for new projects that are ready and worthy of synthesis efforts.
April	**Study Concept Templates** for new directed studies due. Leads for new studies are notified of the need to develop a full proposal within the month.
May	Leads of new synthesis projects developing full proposals conduct outreach to develop teams.
June	**Full Proposals** for new directed studies due to the IEP Program Manager.
June	**Synthesis Team Coordination Meeting:** Current project updates, discuss potential resource gaps for upcoming synthesis projects identified during proposal development.
July	**SMT/CT Review of full proposals** for new directed studies; IEP Program Manager contacts PIs with review outcome and reviewer comments, including requests for re-submission
August	All modified proposals due to the IEP Program Managers.
September	**Coordinator Team** finalizes recommendations for studies to include in the upcoming Annual Workplan
September	**Synthesis Team Coordination Meeting:** Current project updates, continue coordination for upcoming projects
October	
November	

IEP Synthesis Team: Annual Schedule of Planning Tasks and Coordination Activities	
December	**Director Meeting** to finalize the Annual Workplan for the coming year. Request Director Team input for new synthesis work to plan for the next planning cycle.
December	**Synthesis Team Coordination Meeting:** Current project updates, continue coordination for upcoming projects

Who Does IEP Synthesis?

Core Staff for IEP Synthesis

In response to an increasing need for synthesis, IEP agencies have recently sought to bolster the capacity for synthesis activities and have added dedicated IEP synthesis staff positions or re-directed existing positions to synthesis. As of the end of 2018, IEP has a total of five permanent positions: one Program Manager II at DWR, one Senior Environmental Scientist (Supervisor) and two Senior Environmental Scientists (Specialists) at CDFW, and one Research Scientist at the USBR. As needs for individual agencies change, the number of positions dedicated to synthesis may change. These staff devote their time to a variety of tasks, including the following: proposing new synthesis work that is coordinated with IEP science needs (e.g., as described in the IEP Science Strategy), leading individual synthesis projects or technical work groups, contributing to synthesis projects for which they are not lead, communicating synthesis findings, and catalyzing or coordinating projects that may have conceptual support but need help identifying resources. The IEP Lead Scientist also plays a crucial role in identifying, supporting, coordinating, and communicating synthesis work.

Formation of IEP Synthesis Teams

These dedicated IEP synthesis staff provide a “core IEP Synthesis Team”, but do not represent the whole of IEP synthesis work or participants. In fact, each topic-based synthesis team is made up of a unique group of scientists that contribute their own expertise. Along these lines, many analytical teams include the agency scientists that are leads for the collection of the data to be analyzed, as these individuals have a close understanding of the data. However, synthesis teams do not need to be limited to agency scientists. Each individual team may also include scientists from private, academic, or non-governmental affiliations.

Synthesis teams are formed by the lead-person of the team, with input from collaborators. Synthesis team leads may be one of the members of the core staff for IEP synthesis but may also be other IEP scientists. In general, synthesis team leads reach out to appropriate team members as part of the process of developing the full proposal for the IEP process of identifying new directed studies (Table 2), though any of the quarterly synthesis team meetings can be used to brainstorm team membership for upcoming topics.

When forming teams, group size is a key issue. In general, research on key factors contributing to productivity in synthesis teams, is that “dividends” decrease as group size increases (Hampton and Parker 2011). Instead, the diversity of collaborators with respect to discipline, expertise, and affiliation, is a stronger predictor of team success. Thus, IEP synthesis teams strive for diversity with respect to affiliation and discipline such that team members complement one another. However, IEP synthesis teams avoid becoming excessively large to maintain functionality, efficiency and communication. For example, when IEP worked with NCEAS to synthesize the data for the Pelagic Organism Decline (POD), NCEAS recommended keeping teams to 12 or fewer staff. For this reason, synthesis teams will likely not include every possible agency, stakeholder, and discipline because the resulting groups would be too large to be effective. Group size also depends on the topic: there is generally a continuum of group size and staff depending on the complexity of the issue. Some relatively focused topics may be manageable for a few individuals (e.g., leveraging multiple datasets to describe fish communities across several floodplain habitats, Feyrer et al. 2006). Other, larger and more complex topics may require larger teams that incorporate a broader range of expertise (development of a conceptual model to describe current knowledge of Delta Smelt and its habitat, IEP-MAST 2015).

Coordination of Synthesis Teams

To conduct relevant and high-quality synthesis work, IEP synthesis teams must be networked with broad expertise from both science and management communities. The programmatic structure of IEP, including the foundation of expert-based, public Project Work Teams (PWTs) as well as communication between science managers and agency leads, provides a framework to support open, relevant, and responsive synthesis work (Figure 1).

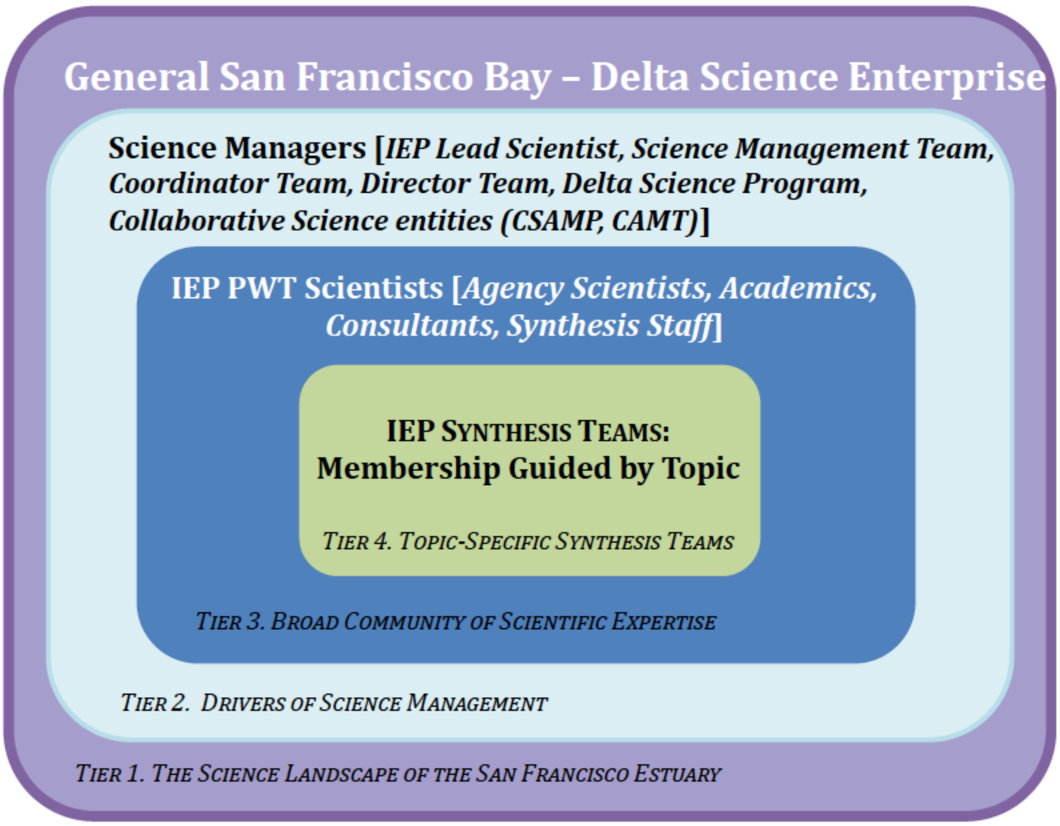

Figure 1. Conceptual framing of how IEP Synthesis teams exist within a framework of both IEP and the broader Science Enterprise of the San Francisco Estuary system (Delta Stewardship Council 2016). CSAMP = Collaborative Science Adaptive Management Program; CAMT = Collaborative Adaptive Management Team.

How Does IEP Communicate its Synthesis Findings?

A critical component of IEP synthesis work is to provide clear, “distilled” information for target audiences (Box 1, Table 1). The successful communication of these findings is a goal for IEP synthesis and for IEP generally. Most synthesis projects, especially those that are included in the IEP Annual Workplan, have a list of target deliverables. Typically, these deliverables include oral presentations at scientific conferences and written products. In addition, each project generally has a PWT to which it will report as the project passes interim milestones. However, to successfully communicate synthesis findings to interested managers, IEP synthesis efforts have used additional modes of communication. In particular, it is important that managers hear directly from synthesis teams on their findings and have an opportunity to ask questions and have a conversation about the implications of the results for management. To do this for synthesis projects that have a clear audience of managers, synthesis teams may require dedicated time in IEP Director meetings or special meetings with relevant managers. For example, a synthesis effort that leveraged a suite of IEP datasets to describe the effects of drought on the

Delta ecosystem produced a fact sheet and provided an oral presentation directly to IEP Directors. It is during the quarterly team meetings of the synthesis leads (to which IEP Coordinator team members are invited), and during other routine IEP meetings, that synthesis team leads can identify and coordinate successful communication strategies in order to directly target their manager audience.

IEP synthesis teams are also broadening their communication strategy to reach potential collaborators outside of the Bay-Delta system. An example of a previous IEP effort to collaborate with an outside group is the engagement in the early 2000s with NCEAS to synthesize the knowledge of many IEP scientists and recent findings to better understand the causes of the Pelagic Organism Decline. This effort resulted in the publication of two peer-reviewed articles (Mac Nally et al., 2010, Thomson et al. 2010). IEP continues to work toward regional and national visibility of its synthesis work by enhancing its open science practices (e.g., publication of IEP datasets on the Environmental Data Initiative, Table 1), which fosters a potential for broader collaboration. When possible, IEP scientists also participate in regional and national conferences. Finally, another avenue through which IEP synthesis strives for integration with relevant groups outside of the Bay-Delta system is by forming direct, task-oriented partnerships with scientists from academic, private, and non-governmental organizations. This outreach to outside groups and scientists is essential to maintaining the vitality and scientific growth of IEP synthesis work as it continues to expand in topic and in the diversity of scientists and expertise that become engaged with IEP.

Appendix: Living Document of IEP Synthesis Products

Peer-reviewed papers.

Brooks, M.L., E. Fleishman, L.R. Brown, P.W. Lehman, I. Werner, N. Scholz, C. Mitchelmore,

J.R. Lovvorn, M.L. Johnson, D. Schlenk, S. van Drunick, J.I. Drever, D. M. Stoms, A. E. Parker, and R. Dugdale. 2012. Life Histories, salinity zones, and sublethal contributions of contaminants to pelagic fish declines illustrated with a case study of San Francisco Estuary, California, USA. *Estuaries and Coasts* 35:603-621.

Brown, L.R. and May, J.T., 2006. Variation in spring nearshore resident fish species composition and life histories in the lower San Joaquin watershed and delta. *San Francisco Estuary and Watershed Science*, 4 (2).

Brown, L.R., Komoroske, L.M., Wagner, R.W., Morgan-King, T., May, J.T., Connon, R.E. and Fangue, N.A., 2016. Coupled downscaled climate models and ecophysiological metrics forecast habitat compression for an endangered estuarine fish. *PloS one*, 11 (1), p.e0146724.

Cloern, J.E., Hieb, K.A., Jacobson, T., Sansó, B., Di Lorenzo, E., Stacey, M.T., Largier, J.L., Meiring, W., Peterson, W.T., Powell, T.M. and Winder, M., 2010. Biological communities in San Francisco Bay track large-scale climate forcing over the North Pacific. *Geophysical Research Letters*, *37*(21).

Cloern, J.E. 2018. Patterns, pace, and processes of water-quality variability in a long-studied estuary. *Limnology and Oceanography* 1 – 17, doi: 10.1002/lno.10958.

Feyrer, F, T. Sommer, and W. Harrell. 2006. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California. *North American Journal of Fisheries Management* 26:408-417.

Feyrer, F., Nobriga, M.L. and Sommer, T.R., 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Sciences*, *64*(4), pp.723-734.

Feyrer, F., T. Sommer and S. Slater. 2009. Old School vs. New School: Status of Threadfin Shad Five Decades after its Introduction to the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 7 (1).

Goertler P.A.L., T. Sommer, W. H. Satterthwaite, B.M. Schreier. Seasonal floodplain-tidal slough complex supports size variation for juvenile Chinook salmon (*Oncorhynchus tshawytscha*). *Ecology of Freshwater Fish* 1–14. https://doi.org/10.1111/eff.12372

Johnson, R. C., S. Windell, P. L. Brandes, J. L. Conrad, J. Ferguson, P. A. Goertler, B. N. Harvey, J. Heublein, J. A. Israel, and D. W. Kratville. 2017. Science advancements key to increasing management value of life stage monitoring networks for endangered Sacramento River Winter-run Chinook salmon in California. *San Francisco Estuary and Watershed Science* 15.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, and S. D. Culberson. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). *Ecological Applications* **20**:1417-1430.

Mahardja, B., Conrad, J.L., Lusher, L. and Schreier, B., 2016. Abundance Trends, Distribution, and Habitat Associations of the Invasive Mississippi Silverside (Menidia audens) in the Sacramento–San Joaquin Delta, California, USA. *San Francisco Estuary and Watershed Science*, 14 (1).

Mahardja B, Farruggia MJ, Schreier B, Sommer T (2017) Evidence of a Shift in the Littoral Fish Community of the Sacramento-San Joaquin Delta. *PLoS ONE* 12(1): e0170683. doi:10.1371/journal.pone.0170683

Polansky, L., Newman, K.B., Nobriga, M.L. and Mitchell, L., 2018. Spatiotemporal Models of an Estuarine Fish Species to Identify Patterns and Factors Impacting Their Distribution and Abundance. *Estuaries and Coasts*, 41(2), pp.572-581.

Scholz, N.L., E. Fleishman, L. Brown, I. Werner, M.L. Johnson, M.L. Brooks, C.L. Mitchelmore, and D. Schlenk. 2012. A perspective on modern pesticides, pelagic fish declines, and unknown ecological resilience in highly managed ecosystems. *Bioscience* 62:428-434

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer,

M. Gingras, and B. Herbold. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary *Fisheries* 32:270-277.

Sommer, T. and Mejia, F., 2013. A place to call home: a synthesis of Delta Smelt habitat in the upper San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 11 (2).

Takata, L, T. Sommer, J.L. Conrad, and B.M. Schreier. 2017. Rearing and migration of juvenile Chinook salmon (Oncorhynchus tshawytscha) in a large river floodplain. Environmental Biology of Fishes. DOI: 10.1007/s10641-017-0631-0

Thomson, J.R., Kimmerer, W.J., Brown, L.R., Newman, K.B., Nally, R.M., Bennett, W.A., Feyrer, F. and Fleishman, E., 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. *Ecological Applications*, 20 (5), pp.1431-1448.

Technical Reports.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, K. Souza. 2010. Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results. Sacramento, CA. https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/sldmwa/baxteretal2010.pdf.

Brown, L. R., R. D. Baxter, G. Castillo, J. L. Conrad, S. Culberson, G. Erickson, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, J. Kirsch, A. Mueller-Solger, S. Slater, K. Souza, and E. Van Nieuwenhuyse. 2014. Synthesis of studies in the fall low-salinity zone of the San Francisco Estuary, September - December 2011. U.S. Geological Survey Scientific Investigations Report 2014-5041:136. http://dx.doi.org/110.3133/sir20145041.

Heublein, J., R. Bellmer, R.D. Chase, P. Doukakis, M.Gingras, D. Hampton, J.A. Israel, Z.J. Jackson, R.C. Johnson, O.P. Langness, S.Luis, E. Mora, M.L. Moser, L. Rohrbach, A.M. Seesholtz, and T. Sommer. 2017. Improved fisheries management through life stage monitoring: The case for the southern distinct population segment of North American Green Sturgeon and the Sacramento-San Joaquini River White Sturgeon. NOAA Technical Memorandum NMFS NOAA TM-NMFS-SWFSC-588. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-588.pdf

Heublein, J., R. Bellmer, R. D. Chase, P. Doukakis, M. Gingras, D. Hampton, J. A. Israel, Z. J. Jackson, R. C. Johnson, O. P. Langness, S. Luis, E. Mora, M. L. Moser, L. Rohrbach, A.

M. Seesholtz, T. Sommer, and J. S. Stuart. 2017. Life history and current monitoring inventory of San Francisco Estuary sturgeon. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-589. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-589.pdf

Interagency Ecological Program Management Analysis and Synthesis Team. 2015. An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish. Interagency Ecological Program Technical Report 90. https://water.ca.gov/LegacyFiles/iep/docs/Delta_Smelt_MAST_Synthesis_Report_January%202015.pdf.

Sherman, A., R. Hartman, D. Contreras, editors. 2017 Effects of tidal wetland restoration on fish: A suite of conceptual models. Interagency Ecological Program Technical Report 91.

Windell, S., P.L. Brandes, J.L. Conrad, J.W. Ferguson, P.A.L. Goertler, B.N. Harvey, J. Heublein, J.A. Israel, D.W. Kratville, J.E. Kirsch, R.W. Perry, J. Pisciotto, W.R. Poytress, K. Reece, B.G. Swart, and R.C. Johnson. 2017. Scientific framework for assessing factors influencing endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) across the life cycle. U.S. Department of Commerce,

NOAA Technical Memorandum NMFS-SWFSC-586. 49p. DOI: http://doi.org/10.7289/V5/TM-SWFSC-586

Published, Citable Datasets.

Interagency Ecological Program (IEP), B. Mahardja, J. Speegle. 2018. Interagency Ecological Program: Over four decades of juvenile fish monitoring data from the San Francisco Estuary, collected by the Delta Juvenile Fish Monitoring Program, 1976- 2017. Environmental Data Initiative. https://doi.org/10.6073/pasta/ea00fc37f0658dae21b817b1f93911cf.

Interagency Ecological Program (IEP), B. Schreier, B. Davis, N. Ikemiyagi. 2018. Interagency Ecological Program: Fish catch and water quality data from the Sacramento River floodplain and tidal slough, collected by the Yolo Bypass Fish Monitoring Program, 1998-2018. Environmental Data Initiative.https://doi.org/10.6073/pasta/0ab359bec7b752c1f68621f5e1768eb0.

References for this Document

Baraniuk, R. G. 2011. More Is Less: Signal Processing and the Data Deluge. Science **331**:717-719. Baron, J. S., A. Specht, E. Garnier, P. Bishop, C. A. Campbell, F. W. Davis, B. Fady, D. Field, L. J. Gross, and S. M. Guru. 2017. Synthesis Centers as Critical Research Infrastructure. Bioscience **67**:750-759.

Brown, L. R., R. D. Baxter, G. Castillo, J. L. Conrad, S. Culberson, G. Erickson, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, J. Kirsch, A. Mueller-Solger, S. Slater, K. Souza, and E. Van Nieuwenhuyse. 2014. Synthesis of studies in the fall low-salinity zone of the San Francisco Estuary, September - December 2011. U.S. Geological Survey Scientific Investigations Report 2014-5041:136 p, http://dx.doi.org/110.3133/sir20145041.

Carpenter, S. R., E. V. Armbrust, P. W. Arzberger, I. I. I. F. S. Chapin, J. J. Elser, E. J. Hackett, A. R. Ives,

P. M. Kareiva, M. A. Leibold, P. Lundberg, M. Mangel, N. Merchant, W. W. Murdoch, M. A. Palmer, D. P. C. Peters, S. T. A. Pickett, K. K. Smith, D. H. Wall, and A. S. Zimmerman. 2009. Accelerate Synthesis in Ecology and Environmental Sciences. Bioscience **59**:699-701.

Cloern, J. E., K. A. Hieb, T. Jacobson, B. Sansó, E. Di Lorenzo, M. T. Stacey, J. L. Largier, W. Meiring, W.

T. Peterson, and T. M. Powell. 2010. Biological communities in San Francisco Bay track large-scale climate forcing over the North Pacific. Geophysical Research Letters **37**.

Delta Stewardship Council. 2016. The Science Enterprise Workshop: Supporting and Implementing Collaborative Science. Proceedings Report http://deltacouncil.ca.gov/docs/science- enterprise-workshop-proceedings-report-nov-1-2-2016.

Halpern, B. S., C. Longo, D. Hardy, K. L. McLeod, J. F. Samhouri, S. K. Katona, K. Kleisner, S. E. Lester, J. O'leary, and M. Ranelletti. 2012. An index to assess the health and benefits of the global ocean. Nature **488**:615.

Hampton, S. E., S. S. Anderson, S. C. Bagby, C. Gries, X. Han, E. M. Hart, M. B. Jones, W. C. Lenhardt, A. MacDonald, and W. K. Michener. 2015. The Tao of open science for ecology. Ecosphere **6**:1- 13.

Hampton, S. E., and J. N. Parker. 2011. Collaboration and productivity in scientific synthesis. Bioscience **61**:900-910.

Heublein, J., R. Bellmer, R. D. Chase, P. Doukakis, M. Gingras, D. Hampton, J. A. Israel, Z. J. Jackson, R.

C. Johnson, O. P. Langness, S. Luis, E. Mora, M. L. Moser, L. Rohrbach, A. M. Seesholtz, T. Sommer, and J. S. Stuart. 2017. Life history and current monitoring inventory of San Francisco Estuary sturgeon. NOAA Technical Memorandum NMFS **NOAA-TM-NMFS-SWFSC-589**.

Johnson, R. C., S. Windell, P. L. Brandes, J. L. Conrad, J. Ferguson, P. A. Goertler, B. N. Harvey, J. Heublein, J. A. Israel, and D. W. Kratville. 2017. Science advancements key to increasing management value of life stage monitoring networks for endangered Sacramento River Winter-run Chinook salmon in California. San Francisco Estuary and Watershed Science **15**.

Lynch, A., R. Thackway, A. Specht, P. J. Beggs, S. Brisbane, E. Burns, M. Byrne, S. Capon, M. Casanova, and P. A. Clarke. 2015. Transdisciplinary synthesis for ecosystem science, policy and management: The Australian experience. Science of the Total Environment **534**:173-184.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, and S. D. Culberson. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications **20**:1417-1430.

Mitchell, L., K. B. Newman, and L. Polansky. 2017. Design-based estimates of Delta Smelt abundance. US Fish and Wildlife Service, Bay-Delta Fish and Wildlife Office Delta Smelt Model Technical Note 2.

Polansky, L., L. Mitchell, and K. B. Newman. 2018a. Model-assisted design-based estimation of Delta Smelt abundance indices U.S. Fish and Wildlife Service, Bay-Delta Fish and Wildlife Office. Delta Smelt Model Technical Note 6.

Polansky, L., K. B. Newman, M. L. Nobriga, and L. Mitchell. 2018b. Spatiotemporal Models of an Estuarine Fish Species to Identify Patterns and Factors Impacting Their Distribution and Abundance. Estuaries and Coasts **41**:572-581.

Sherman, S., R. Hartman, D. Contreras, and editors. 2017. Effects of Tidal Wetland Restoration on Fish: A Suite of Conceptual Models. IEP Technical Report 91. Department of Water Resources, Sacramento, California.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, and B. Herbold. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary: El colapso de los peces pelagicos en la cabecera del Estuario San Francisco. Fisheries **32**:270-277.

Thomson, J. R., W. J. Kimmerer, L. R. Brown, K. B. Newman, R. M. Nally, W. A. Bennett, F. Feyrer, and

E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications **20**:1431-1448.