Indian River Lagoon Ecological Health Assessment

METHODOLOGY REPORT: VERSION 2.0 (REPORTING 2017-2019)

AUGUST 17, 2020

PREPARED FOR:

Marine Resources Council

PREPARED BY:

APPLIED ECOLOGY INC

Contents

Acknowledgements

The original methodology report (Year 1, 2017) was completed with input and assistance from the Indian River Lagoon Science Technology, Modeling and Monitoring Peer Review subcommittee members, Anne Birch, David Cox, Duane De Freese, Chuck Jacoby, and Lisa Krimsky. Funding for the original report was provided by the Indian River Lagoon National Estuary Program Grant # IRL2016-021 (Encumbrance # GL01-1829 & GL010-1886). This report update was supported by the kind donation and efforts of private foundations and individuals that want to protect and restore the Lagoon. In addition, this effort could not have been completed without the assistance, advice, and guidance from many individuals, especially Margie Lasi, Lori Morris, Ron Brockmeyer, Wendy Tweedale at St. Johns River Water Management District, Patti Gorman and Mike Tompkins at South Florida Water Management District, Thomas Adams at Florida Department of Environmental Protection, Jessica Lunt and Tom Opishinski at Smithsonian Marine Station, Graham Cox from the National Audubon Society, and Karen Henshen, Laura Markley, Rhonda Bailey, Rich Paperno, and Steve Brown at the Florida Fish and Wildlife Conservation Commission. A special thank you to Bud Howard, Sue Noel, and Rachel Harris (Loxahatchee River District), Boyd Gunsalus from the SFWMD, and Dr. Mark Perry and Pam Hopkins from the Florida Oceanographic Society for the assistance in expanding the original methodology to tributaries in the Lagoon.

Introduction

In early 2014, the Marine Resources Council (MRC) led the Lagoon Action Assembly where a large group of stakeholders prioritized the development of a “State of the Lagoon” report similar to several other available Report Cards, such as the Chesapeake Bay Foundation Report Card and the Puget Sound Action Agenda Report Card. The goal of the “State of the Lagoon” report would be twofold:

1. Define appropriate pollutant, habitat, species, socio-economic, and behavioral metrics
2. Report monitoring results back to the community in appropriate formats

The development of the Indian River Lagoon (IRL) Ecological Health report was initiated in 2015 with the Science Assembly led by the University of Maryland Center for Environmental Science. The Science Assembly involved over sixty diverse Lagoon scientists who focused on the following:

- Defining the priorities of the initial report card effort (ecological health)
- Proposing reporting regions and scale of the initial effort (five reporting regions were identified based on the four Basin Management Action Plan boundaries, plus Mosquito Lagoon)
- Defining Indian River Lagoon specific indicators of health
- Identifying potential sources of data for the proposed indicators

As an outcome of the Science Assembly, Applied Ecology, Inc. partnered with MRC to initiate the extensive data collection, organization, management, and then analyses in preparation to complete the first ecological health assessment of the Indian River Lagoon. The work to synthesize data from multiple agencies and academic providers to analyze the complex ecological condition of the Indian River Lagoon was initiated in October 2016, and the final product was produced in 2018. Efforts to expand the spatial and temporal extents for the second ecological health assessment of the Indian River Lagoon began in January 2019 and were completed in late December 2019. Efforts were made possible with funding from the Indian River Lagoon National Estuary Program (IRLNEP) and several local family foundations and the decades-long devotion of multiple agencies, research institutions, municipalities, and non-profit organizations to acquire as much data as possible from the vast 335 sq. miles of Lagoon waters and 2,205 sq. miles of watershed. Two main tasks were completed under the Year 2 Report project:

- Task 1: Update the current metrics for the IRL proper for the next analysis year (2017) using the previously established targets
- Task 2: Expand the spatial boundary to include major tributaries which lead into the IRL, establish targets for existing metrics of each tributary, perform statistical analyses, and task reporting reporting

This report is associated with Task 2, which included updating the existing methodology used in the scientifically rigorous ecological assessment of the Lagoon to include the major tributaries. The Methodology Report includes a detailed discussion of how ecological indicators were initially selected and refined after data acquisition and analysis. The indicators fall under two broad categories: water quality and habitat. Previously, the IRLNEP Peer Review Committee was involved in evaluating indicators, identifying targets, and testing scoring methods throughout the process. This methodology report describes these processes in detail and summarizes the development of a site-specific water quality index, which incorporates several of these ecological indicators.

Ecological Indicator Selection

Ecological indicators defined at the Lagoon Science Assembly were evaluated based on the availability of adequate temporal and spatial data to represent the lagoon and the presence of an existing regulatory or scientifically-based target. The preliminary list of indicators was presented to the STEM Committee on May 9, 2017 (Appendix A). The initial proposed list of indicators was all-encompassing and included four different types of data:

1. Water Quality Indicators
2. Habitat and Benthic Indicators
3. Fisheries and Shellfish Indicators
4. Wildlife Indicators

After feasibility analysis of each of the proposed indicators within the four categories, a much smaller subset of indicators was selected for consideration. An indicator was determined to be feasible if adequate temporal and spatial coverage of data existed. Feasible indicators that had an existing scientific or regulatory target are noted as "Selected" in the Indicator Analysis Table. These correspond to indicators that might eventually be able to be used in future efforts if additional analyses and consensus on appropriate targets can be agreed upon by the scientific community (Figure 1).

Figure 1. Potential Ecological Health Indicators for future analyses of the Status of the Indian River Lagoon report.

After discussions with the IRLNEP STEM committee and peer review team, a consensus was achieved to only include indicators with already approved targets for the initial ecological health assessment. Few indicators within the water quality and benthic/habitat groups had ready-to-use targets that had been previously vetted by the scientific community. Figure 2 includes the recommended indicators for inclusion in the detailed statistical analysis process to better understand trends. Data for all these indicators were acquired, organized, analyzed, and compared to the existing Indian River Lagoon specific targets.

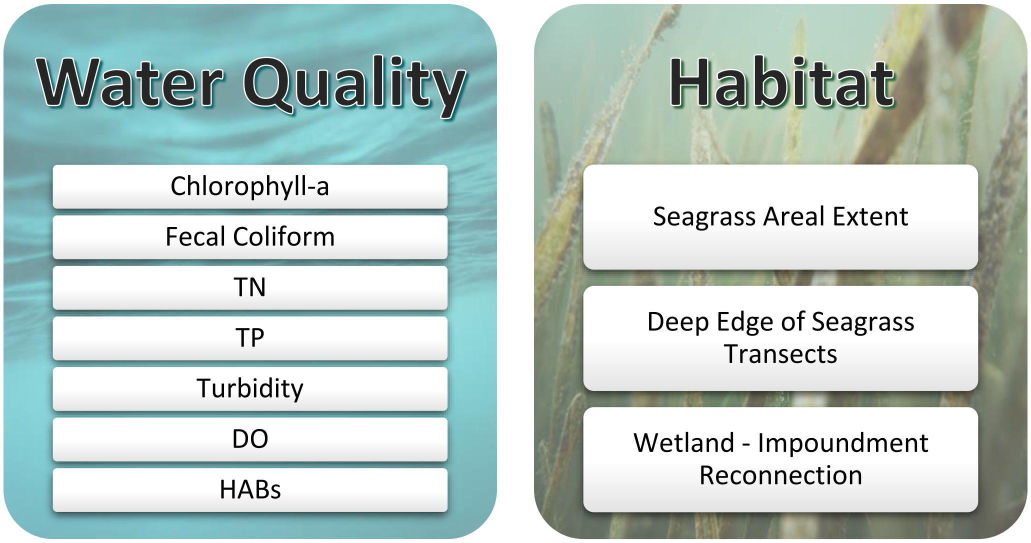

Figure 2. Recommended parameters to be used as ecological indicators for the 2016 IRL Ecological Health Assessment.

Results from these analyses were then used to further filter the indicators that could be used confidently in the first Ecological Health Assessment, eliminating additional indicators that fell under the following categories:

- Indicators with not enough dense spatial or temporal availability, particularly for 2016 (*e.g.*, fecal coliform had no data available after June 2016 and none for the entire Banana River watershed)
- Indicators that would only be available or updated biennially and for which there is inadequate data coverage to accurately represent annual variability (*e.g.*, seagrass areal; interannual variability is too high to allow the use of the previous year's data in an annual assessment)Indicators that are not collected in the most appropriate method to allow testing against available targets (*e.g.,* dissolved oxygen minimum targets cannot be truly tested since these are often encountered in the night/early dawn hours when sampling doesn't take place)
- Indicators with no targets or with targets that are still in the development stage (*e.g.,* HABs, salinity, pH)

For the reasons listed above, dissolved oxygen, fecal coliform, HABs, salinity, seagrass areal extent, and wetland impoundment reconnection were eliminated as indicators in the 2016 IRL Ecological Health Assessment. Details on the status and reason for current exclusion for each of the indicators of interest follow below.

For DO, the EPA established surface water quality standards that are comprised of a multi-rule system, including a daily average, a seven-day average, and a 30-day average DO percent saturation (EPA 2015) standard. This system would require intensive daily grab sampling (once to three full days) throughout our period of record to properly assess if the targets were being achieved. Upon reviewing the data, it was discovered that such sampling intensity has never been conducted for DO in the Indian River Lagoon. In addition, the Florida Department of Environmental Protection (FDEP) proposed state water quality criterion for DO is a minimum, which would be more practical to enforce. However, the available DO data are typically collected during working hours, not typically representative of lower saturation levels of DO. Most of the DO minima extracted for the dataset are likely inflated; furthermore, since sampling takes place at inconsistent times throughout the workday, comparisons between years could be masked by daily variations. Time of day corrections outlined in FDEP's Technical Support Document "Derivation of Dissolved Oxygen Criteria to Protect Aquatic Life in Florida's Fresh and Marine Waters" (FDEP, 2013) could be used in time of day for data collection has been consistently assigned to all the readings.

Although there are well established targets for fecal coliform, they are not sublagoon specific and the data itself did not spatially or temporally cover the extent of the IRL for the 2016 year; there were no data within the Banana River Lagoon (BRL) or the South Indian River Lagoon (SIRL) South and the remaining data only spanned until June of 2016. Additionally, a majority of the fecal coliform samples appear to be concentrated in specific spatial areas during isolated events, resulting in inconsistent spatially and temporally variable data that are not comparable to the regularly sampled ambient water quality monitoring. For this reason, fecal coliforms are not being included in the initial water quality index.

Currently, no targets have been established in any region of the IRL for HAB events. Although data were received from both FWC Fish and Wildlife Research Institute (FWRI) and St. Johns River Water Management District (SJRWMD), different methods are used when collecting bloom data. The majority of HAB data collected by FWRI are opportunistic, as collection usually is a response to the report of a bloom occurring. As a result, HAB data are denser in years and locations where higher effort was expended, resulting in potential bias for interannual comparisons. The SJRWMD performs monthly sampling at several designated stations, however, there are no monitoring stations located within the southern portions of the IRL, resulting in incomplete spatial coverage in a region of the lagoon where HABs are of significant concern. Additionally, FWRI uses cell counts as their unit of measurement, while SJRWMD uses biovolumes, making the data incomparable.

Salinity targets have only been set by the South Florida Water Management District (SFWMD) for the south IRL. As there was not complete spatial coverage for the salinity targets, and these appear to be of specific importance near tributaries (currently not included in the first assessment effort), this indicator was not selected for further consideration in the 2016 Indian River Lagoon Ecological Health Assessment.

The seagrass areal extents were removed as the habitat indicators for several reasons: 1) seagrass coverage targets have yet to be defined for the SIRL, while dozens of transects within the SIRL have established TMDL targets; 2) areal seagrass extents are only measured biennially so annual changes could not be calculated or applied to the current report year (2016); and 3) attempting the use of two related indicators (seagrass areal coverage and seagrass transect length) in some years and not in others increases the variability of the results and introduces some inherent error in some years and not others.

Total wetland coverage within the watershed or surrounding the IRL shoreline is not currently established and well-accepted by the scientific community. Most of the wetland impoundments targeted for reconnection have already been restored, and the few outstanding ones are unlikely to take place at a high enough rate for changes in a health assessment score to change annually. For this reason, wetland impoundment reconnection will be used only as a success story in restoring the IRL in the past couple of decades.

Figure 3 provides the step by step process in how variables were analyzed and selected during the several phases of analyses during this project. It is important to note that several of these indicators are likely to be considered again in the future once targets are established or the spatiotemporal representativeness of the data is improved.

The remainder of the methodology report includes a description of the methodology implemented for the four selected water quality indicators of interest (chlorophyll-a, TN, TP, and turbidity) and the selected habitat indicator (seagrass transect length).

DATA TYPE	INDICATOR	DATA ACQUISTION		DATA PROCESSING		INDEX CALCULATION		COMMENTS
		Indicator Selection	Data Acquistion	Spatial Coverage	Temporal Coverage	Established Targets	Final Index Calculation	
Water Quality	Chlorophyll-a							No SIRL South Coverage
	Dissolved Oxygen							Not sampled to test target
	Fecal Coliform							Incomplete temporal and spatial 2016 coverage
	HABs							No SIRL SJRWMD data
	pH							Targets lack spatial resolution
	Salinity							Targets lack spatial resolution
	Total Nitrogen (TN)							No SIRL South Coverage
	Total Phosphorus (TP)							No SIRL South Coverage
	Turbidity							No SIRL South Coverage
Habitat	Seagrass Aerial Extent							Biannual data; No SIRL targets
	Seagrass Transect Depth							
	Wetland Coverage Extent							Data produced every five years
	Wetland Impoundment							Little to no variation (near target)
Wildlife	Fish Abnormalities							No targets
	Keystone Species Abundance							No targets
	Iconic Species Abundance							No targets
	Tropical Peripheral Abundance							No targets
	Brown Pelican Abundance							No targets
	Manatee Mortality							No targets
	Sea Turtle Stranding							No targets

Figure 3. Flowchart of the indicator selection process used for the 2016 IRL Ecological Health Assessment. Solid colored cells indicate completed process, cross-hatch means the indicator was removed at that process, dotted partially applicable and included in the final indicator selection. Comments are provided for any removed indicators during any of the stages of the analytical process.

WATER QUALITY INDICATORS

Data Acquisition

Both the SJRWMD and SFWMD advised that data prior to 1996 were inadequate because reliable quality assurance measurements were only implemented after 1995. Thus, the period of record chosen for the water quality parameters, except for HABs, during the second year of the IRL Ecological Health Assessment ranged from January 1st, 1996 to December 31st, 2017. More than 3 million records were acquired, processed, and culled prior to populating the database for mapping and analysis.

All data for chlorophyll-a, total nitrogen (TN), total phosphorus (TP), and turbidity were acquired independently from both water management districts, the Loxahatchee River District (LRD), as well as the FDEP Watershed Services Program. The SJRWMD and FDEP data were downloaded from separate FTP servers, the LRD data was received through direct data request to the District, and the SFWMD data were downloaded from the DBHYDRO online database.

Data Processing

Study Area

All data received were associated with a specific spatially referenced monitoring station. During the first year of the IRL Ecological Health Assessment, the study area was defined as the entire Indian River Lagoon represented as ten Sublagoon regions (Figure 4), and accompanied by an additional 50-meter buffer to ensure no incorrectly located data would be missed accidentally.

During the second year of assessment, the spatial extent of the study area was increased to include the following tributaries from north to south (Figure 5, Figure 6):

- Turnbull Creek
- Big Flounder Creek
- Horse Creek
- Eau Gallie River
- Crane Creek
- Turkey Creek
- Goat Creek
- Sebastian River Estuary
- Taylor Creek
- St. Lucie River Estuary
- Loxahatchee River Estuary

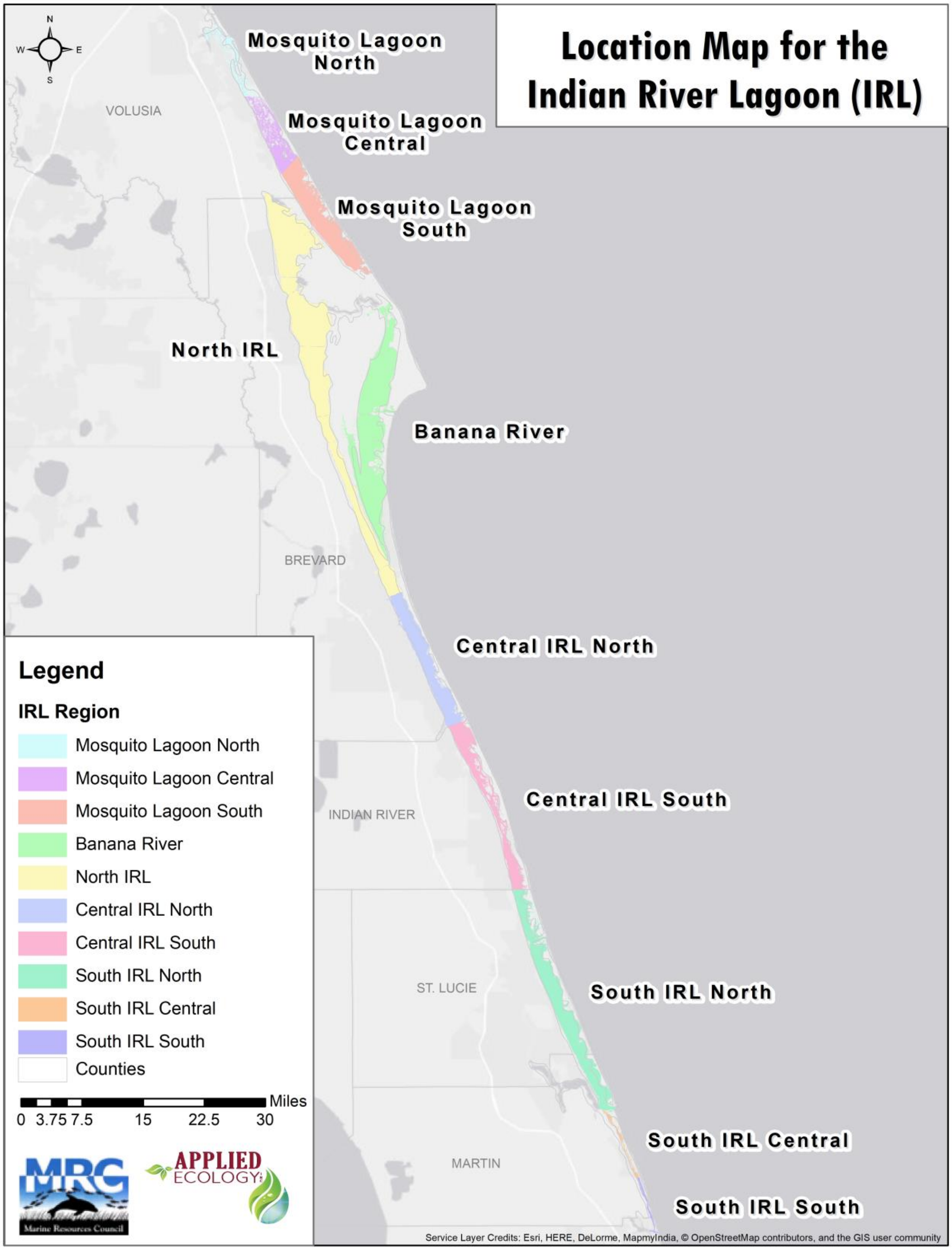

Figure 4. Locator map for the 10 Sublagoon region used for IRL Proper assessment effort.

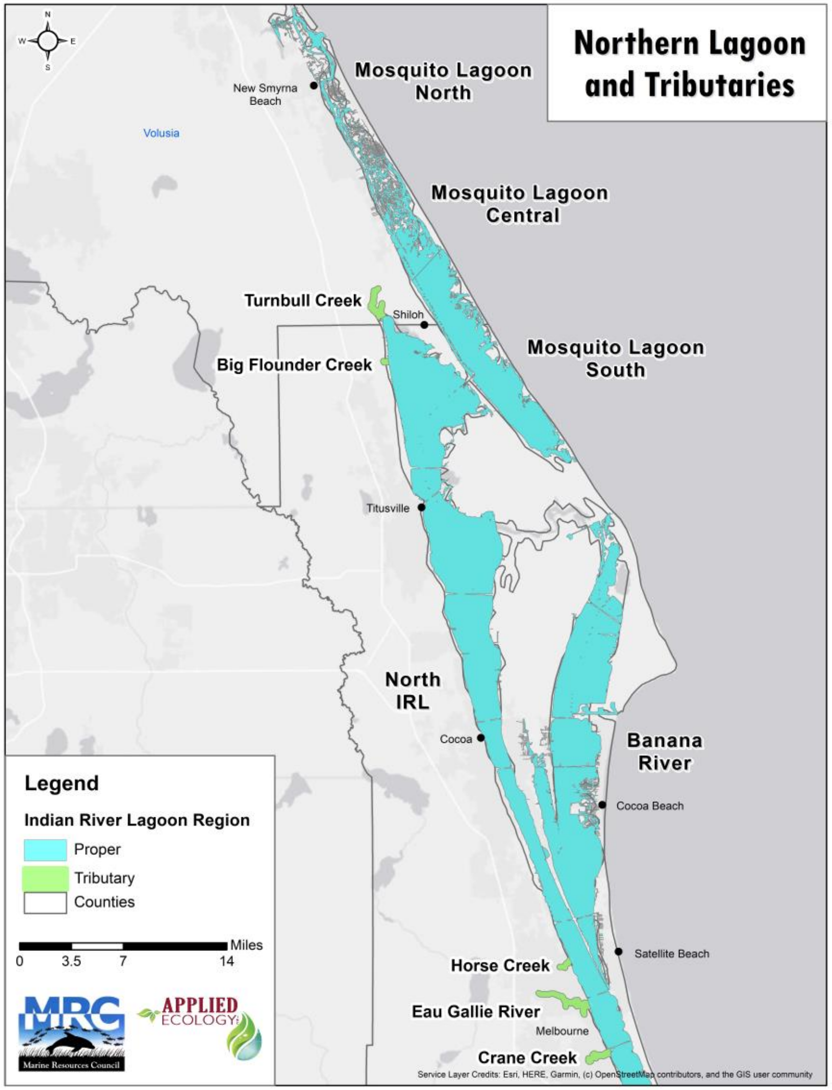

Figure 5. Locator map for the northern portion of the IRL and associated tributaries.

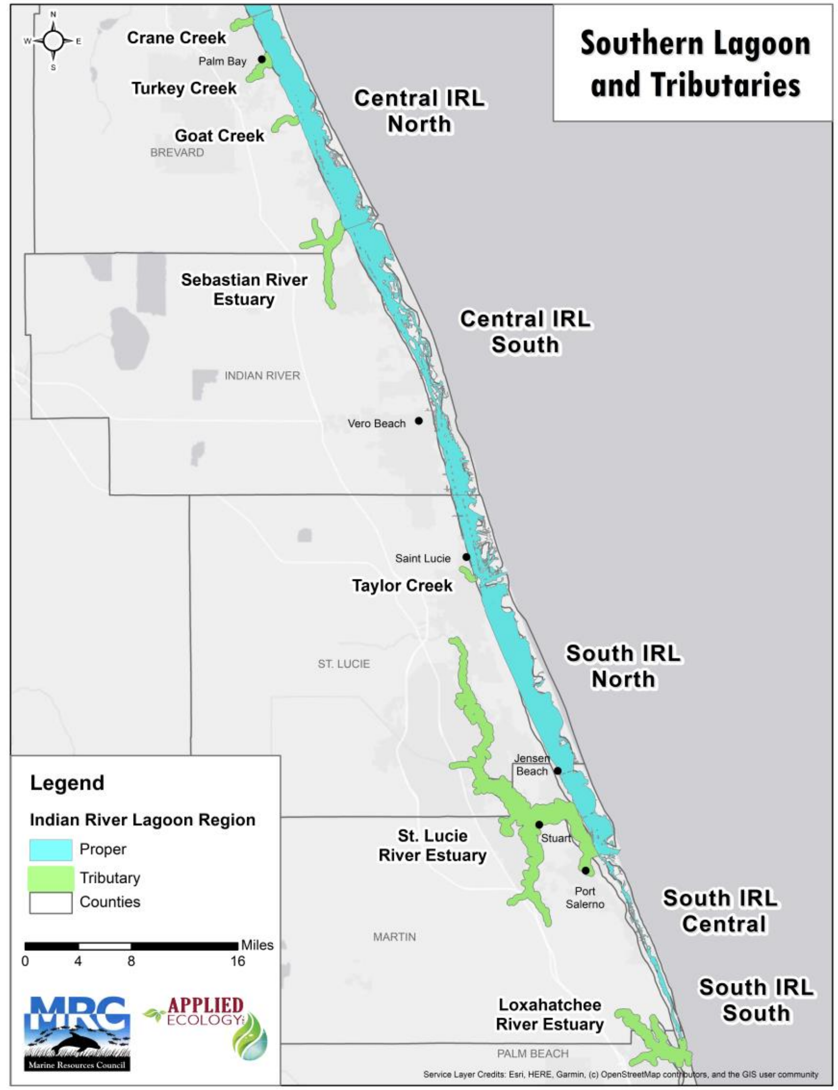

Figure 6. Locator map for the southern portion of the IRL and associated tributaries.

It should be noted that only stations located within the buffered study area of the IRL proper or directly within the confines of the natural, unaltered tributaries were included in the study. Addison Creek (located in Titusville, just north of the Titusville Cocoa Airport) was not included as there are no active monitoring stations. Data for the selected stations were further processed and analyzed such that stations with questionable spatial reference or stations without at least quarterly data were removed from the analysis. The database developed for this project only included stations meeting these quality control procedures.

General Rules: Chlorophyll-a, TN, TP, and Turbidity

The SJRWMD, SFWMD, LRD, and FDEP datasets were processed separately as their datasets were not congruent.

All matrices aside from “Water”, “Surface Water”, or “Saline” (SFWMD specific) were removed from each dataset. The “GRAB”, “P01”, and “DUP” sample types from SJRWMD, the “SAMP” sample type from SFWMD, and “Sample”, “Field”, or “Field Msr/Obs” sample types from the FDEP dataset were selected. When possible, data from autosamplers were also used from the SFWMD; records selected were specific to the auto-sampler composite flow (“ACF”) proportional collection method. A new column in the database was created to identify either a manual surface water grab (“M”) or a surface water grab collected by an autosampler (“A”). Other samples that were eliminated in this process included: profile samples taken at other depths besides the one at the standard depth for ambient water sampling depths (0.5 m), duplicate samples, blanks, or soil samples. When multiple grab samples were taken on the same day, *i.e.,* a regular grab sample and a duplicate sample, only the first recorded sample for that day was used.

Seasonality was also accounted for during data processing, with time-series data kept intact and related to the spatial location. In addition, a new column was added to associate all data with either the wet season (collected between June-October and classified using a “W”) or dry season sample (November-May and classified using a “D”).

Sampling depths for the SJRWMD water quality datasets were provided in separate tabular inputs from the analytical results. Data were joined using date/time fields and unique site identifiers to populate sampling depths; for the few records with no associated sampling depth, the sampling depth was assigned to half of the maximum depth or 0.5 m, whichever was smallest.

If the analytical result for a specific parameter was negative or below a given method detection level (MDL), the analytical result value was replaced with the MDL value. All instances of this substitution were assigned a custom “ND” qualifier, indicating the value was replaced by Applied Ecology, Inc., even if the records were already qualified using a “U” qualifier code (indicative of an analytical result having a concentration lower than the MDL value). If the analytical result value was negative and a corresponding MDL value was not present, then the analytical result value was left unaltered and a comment was added to the Comments field. The substitution by the MDL value was typically done in the SFWMD datasets and applied to the SJRWMD datasets during data processing for consistency.

The data from all the available sources included extensive use of qualifiers, which were carefully screened and processed applying the following specific rules:

- If the qualifier field ("Remark Code") was “A”, "G", "J", "J,A", "O", "V", "Y", ">", "?", or a combination using one of these qualifiers, then the record was removed from the dataset.
- If the qualifier field ("Remark Code") was a “K” or "W" (SJRWMD internal code), then the Analytical Result value was replaced with the MDL value.
- If the qualifier field ("Remark Code") was "Q", the following rules were applied depending on the parameter:
    - TKN: If the hold time for TKN is over 45 days, then the record was removed from the dataset.
    - All other parameters: The record was removed from the dataset.
    - "J" and "T": The result value was replaced with the MDL value.

As some records had more than one qualifier applied, multiple fields were created. If more than one qualifier was present, then the proceeding Qualifier fields were populated as needed (*e.g.,* if three qualifiers were present, the Qualifier1, Qualifier2, and Qualifier3 fields would all be populated). The following rules were applied when more than one qualifier was present or additional qualifiers were assigned:

- If the qualifier field ("Remark Code") was a combination of "J" and another qualifier, the following rules were applied:
    - "J" and "I": If the result value is greater than the PQL value or less than the MDL value, then the record was removed from the dataset.
    - "J" and "U": If the result value is not equal to the MDL value, the record was removed from the dataset.
- If the qualifier field ("Remark Code") was an "I", the following rules were applied:
    - If the result value is greater than the MDL value and less than the PQL value, then an "I" qualifier was assigned to the record.
    - If the result value is equal to the PQL value, then an "I" qualifier was assigned to the record.
    - If the result value was greater than the PQL value and an "I" qualifier was assigned by the WMD, then the "I" qualifier was removed.
- If the qualifier field ("Remark Code") was an "ND", the following rules were applied:
    - If the result value was replaced with the MDL, an "ND" qualifier was assigned to the record.
    - If the result value is less than the MDL and the WMD did not assign a non-detect code (*i.e.,* "U", "W", or "T"), then an "ND" qualifier was assigned to the record.
- When the qualifiers deemed certain samples as a “non-detect” value ("U", "W", "T", or "ND"), the non-detect field was set to "Y".

Parameter Specific Rules: Chlorophyll-a, TN, TP, and Turbidity

Certain rules were applied depending on a particular water quality indicator when necessary.

- Chlorophyll-a: Only “Corrected” chlorophyll-a values were used.
- Total nitrogen:
    - For data acquired from the SFWMD, LRD, or FDEP, total nitrogen values were calculated by adding Total Kjeldahl Nitrogen (TKN-T) and Nitrate-Nitrite (NO_X-T) when it was not already calculated or provided for a specific station/event.
    - For data acquired from the SJRWMD, only reported TN values were used directly for analysis, since these values were provided for most of the stations and events of interest

Establishing Targets for Relevant Ecological Water Quality Health Indicators

The water quality indicators were based on available regulatory limits that are specific to the Indian River Lagoon. Regulatory targets are specific to the reporting region (aka sublagoon regions or tributary segments) and included the following sources:

1) Chapter 6-302: Surface Water Quality Standards (EPA, 2015)
2) FDEP site-specific standards for the Mosquito Lagoon (FDEP, 2014)
3) Using multiple lines of evidence for developing numeric nutrient criteria for Indian River and Banana River lagoons, Florida (Steward, Lasi, and Phlips, 2010)
4) Water quality target development in the Southern Indian River Lagoon (Crean, Robbins, and Iricanin, 2007)
5) Chapter 62-304: Total Maximum Daily Loads (FDEP)
6) TMDL Report Nutrient and Dissolved Oxygen TMDLs for the Indian River Lagoon and Banana River Lagoon (Gao, 2009)
7) TMDL Report Dissolved Oxygen and Nutrient TMDLs for Eight Tributary Segments of the Indian River Lagoon (Gao and Rhew, 2013)
8) TMDL Report Nutrient and Dissolved Oxygen TMDL for the St. Lucie Basin (Parmer, Laskis, McTear, and Peets, 2008)
9) Mosquito Lagoon Reasonable Assurance Plan (RAP) (Cunningham, 2019)

Depending on the water quality indicator, additional peer-reviewed sources might have been used to supplement the regulatory sources above, when these were not available for all sublagoons. Table 1 provides an overview of the sources used to establish the targets for each of the selected water quality indicators.

Table 1. Sources of established targets for each water quality parameter.

Source	Chlorophyll-a	Total Nitrogen (TN)	Total Phosphorus (TP)	Turbidity
(1) EPA Surface Water Quality Standard Chapter 62-302	X	X	X	X
(2) FDEP site-specific standards for the Mosquito Lagoon (FDEP, 2014)	X	X	X	
(3) Steward, Lasi, and Phlips (2010)	X	X	X	X
(4) Crean, Robbins, and Iricanin (2007)	X	X	X	X
(5) FDEP Total Maximum Daily Loads Chapter 62-304		X	X	
(6) Gao (2009)		X	X	
(7) Gao and Rhew (2013)		X	X	
(8) Parmer, Laskis, McTear, and Peets (2008)		X	X	
(9) Cunningham (2019)	X	X	X	

Throughout the remainder of this report, source (1) will simply be referred to as "EPA targets", sources, (2), (5), (6), (7), and (8) as "FDEP Targets", source (3) as "SJRWMD Targets", and source (4) as "SFWMD Targets". Sources created specific targets for either each sublagoon/ tributary area or they have further divided these areas into smaller subsections which shall be referred to as sublagoon regions or tributary segments. For example, there are three sublagoon regions (North, Central, and South) of the Mosquito Lagoon. The Mosquito Lagoon, Central Indian River Lagoon, South Indian River Lagoon, Sebastian River Estuary, St. Lucie Estuary, and Loxahatchee River Estuary all have site-specific targets for two to three regions/segments each.

Due to the size and complexity of the Lagoon, each area of the IRL and its associated tributaries exhibit drastically different behaviors in water quality. The system variability is directly related to flushing times of a particular area, watershed/estuary ratio, predominant land uses, volumes discharged by managed canals, among others. The goal of the Ecological Health Assessment is to assess and communicate the site-specific health of the Lagoon using the finest spatial resolution possible. To achieve this, the targets for each sublagoon region or tributary segment were selected over the broader Lagoon-wide targets, when possible. For example, instead of using one single target for all of Central Indian River Lagoon (CIRL), a different one was used for each of the North and South CIRL areas. If only one target was available for a specific criterion, that same target was adopted for the ecological health assessment. Similarly, when only one target was available for a specific area, that target was used. If alternative targets were proposed by multiple agencies for a specific area, the decision to choose a particular target is explained in the subsections below.

Chlorophyll-a

IRL Proper

For the IRL proper, targets created by the EPA/FDEP and SJRWMD were considered for the Mosquito Lagoon (ML), Banana River (BRL), North IRL (NIRL), and Central IRL (CIRL) while the EPA/FDEP and SFWMD targets were considered for the South IRL (SIRL) (Table 2).

One of the challenges to chlorophyll-a targets is that the EPA/FDEP targets use annual geometric means while the Water Management Districts targets use annual medians. SJRWMD targets are used for the BRL, CIRL, and NIRL, and those established by the EPA/FDEP are used for the ML and SIRL. Two things were noted when considering the chlorophyll-a targets: (1) the application of the targets to regions of the sublagoon areas is not consistent between sources (geometric means and medians are used in as measures of central tendency depending on the location); (2) sources the EPA/FDEP targets specify the annual geometric mean should not be exceeded more than once in a three-year period.

After a comparison of the criteria from each source, it was decided that a combination of the established targets would be used in the Indian River Lagoon Ecological Health Assessment (bolded in Table 2). For the ML, the selected target was derived from those established by the EPA/FDEP. These values were also used in the most recent update of the Mosquito Lagoon Reasonable Assurance Plan (Cunningham, 2019). However, our intended purpose of this assessment is to provide annual reporting on the status of the IRL. Thus, exceedances from proposed targets are calculated annually as opposed to the EPA/FDEP's method of examining exceedances over a three-year period. For the BRL and NIRL, there are three potential available targets to choose from: monthly maxima, annual medians, and annual geometric means. The SJRWMD annual median target was selected as the chlorophyll-a data were not consistently collected monthly for each station. In addition, geometric means (EPA/FDEP recommended target) were typically less protective of the Lagoon than the District's median targets. For the CIRL, the SJRWMD annual median targets specific to the north and southern regions (3.0 µg/L and 3.6 µg/L, respectively) were selected (Steward, Lasi, and Phlips, 2010). Finally, for the SIRL, the SFWMD's conservative criteria of an annual median of 3.1 µg/L was used as the target for all three sublagoon regions.

Table 2. Chlorophyll-a targets established by the major sources for specific sublagoon areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Sublagoon Region	EPA/FDEP	SJRWMD		SFWMD
		Annual	Monthly	
ML - North	**AGM < 4.0 µg/L**			
ML - Central	**AGM < 3.4 µg/L**			
ML - South	**AGM < 2.5 µg/L**			
BRL	AGM < 7.3 µg/L	**AM ≤ 4.7 µg/L**	Maximum ≤ 17 µg/L	
NIRL	AM < 6.4 µg/L	**AM ≤ 4.6 µg/L**	Maximum ≤ 24 µg/L	
CIRL - North	AGM < 5.9 µg/L	**AM ≤ 3.0 µg/L**		
CIRL - South		**AM ≤ 3.6 µg/L**		
SIRL - North	AGM < 4.7 µg/L			**AM ≤ 3.1 µg/L**
SIRL - Central	≤ 10% exceedances over 7 years > 6.9 µg/L			
SIRL - South	AGM < 2.0 µg/L			
AGM = Annual geometric mean; AM = Annual median				

IRL Tributaries

For the IRL tributaries, targets created by the EPA/FDEP were considered for the Eau Gallie River, Goat Creek, the Sebastian River Estuary (estuary segment only), St. Lucie River Estuary (all segments with the exception of the Winding South Fork), and Loxahatchee River Estuary. No site-specific targets exist for Turnbull Creek, Big Flounder Creek, Addison Creek, Horse Creek, Crane Creek, Turkey Creek, Taylor Creek Canal, or the Winding South Fork segment of the St. Lucie River.

Although the only source of targets were those of the EPA/FDEP, similar challenges in chlorophyll-a target selection for the IRL proper were also experienced within the tributaries: (1) the application of the targets to subsections of the tributary areas is not consistent between sources (*e.g.,* annual geometric means versus descriptive narratives which are not site-specific; (2) the annual geometric mean should not be exceeded more than once in three-year period.

EPA/FDEP concentration targets were selected for the St. Lucie (with the exception of the Winding South Fork and Bessey Creek) and Loxahatchee River Estuaries, as these were site-specific and the only available targets. However, exceedances from the proposed targets would be calculated annually rather than a three-year period, the same method proposed for EPA/FDEP targets of the IRL proper.

For the tributary segments without targets discussed above, the selected targets of the IRL proper sublagoon region in which the tributary directly connected were applied. For example, Turnbull Creek is connected to the NIRL; thus, the SJRWMD annual median target of 4.6 µg/L was applied. Although these targets are not the most accurate representation of the water quality in the tributaries due to various hydrological differences (flow, residence time, etc.), this decision was based on the rationale that these tributaries are included in the spatial extents of either the BMAP or TMDL boundaries for the associated IRL Proper region. This method was also applied to tributaries or segments of tributaries which have narrative guidance, rather than site-specific targets from the EPA/FDEP (*i.e.*, the Eau Gallie River, Goat Creek, and St. Lucie River's Bessey Creek). An exception of the rule was made for the Winding South Fork of the St. Lucie River estuary; the target of the closest tributary segment (the Upper South Fork of the St. Lucie River) rather than the closest IRL proper sublagoon region was assigned, as it had a site-specific concentration target that was considered more representative of water quality conditions within that waterbody. Additionally, the Sebastian River Estuary had an EPA/FDEP target for the main estuary segment target; however, this did not include the North or South Prongs. It was decided that the SJRWMD targets for the CIRL North sublagoon would be applied to all segments of the Sebastian River Estuary in order to remain consistent with the specific methods instructed by the IRL Tributary TMDL for other parameters used in the IRL Ecological Health Assessment.

Table 3. Chlorophyll-a targets established by the major sources for specific tributary areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Tributary Segment	EPA/FDEP	In-House	Comments
Turnbull Creek		**AM ≤ 4.6 µg/L**	No target, but covered under the spatial extent of the NIRL BMAP; Applied SJRWMD Target for NIRL
Big Flounder Creek		**AM ≤ 4.6 µg/L**	No target; WBID included in NIRL TMDL; Applied SJRWMD Target for NIRL
Addison Creek		**AM ≤ 4.6 µg/L**	No target, but covered under the spatial extent of the NIRL TMDL; Applied SJRWMD Target for NIRL
Horse Creek		**AM ≤ 4.6 µg/L**	No target, but covered under the spatial extent of the NIRL TMDL and BMAP; Applied SJRWMD Target for NIRL
Eau Gallie River	Narrative	**AM ≤ 4.6 µg/L**	Site-Specific NNC, but in narrative format; Applied SJRWMD Target for NIRL
Crane Creek		**AM ≤ 4.6 µg/L**	No target; Applied SJRWMD Target for CIRL North
Turkey Creek		**AM ≤ 3.0 µg/L**	No target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for NIRL
Goat Creek	Narrative	**AM ≤ 3.0 µg/L**	Site-Specific NNC, but in narrative format; Applied SJRWMD Target for CIRL North
Sebastian River Estuary	AGM < 5.9 µg/L	**AM ≤ 3.0 µg/L**	Site-specific NNC concentration target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for CIRL North to be consistent with other parameters
Sebastian River Estuary - North Prong		**AM ≤ 3.0 µg/L**	No target; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - South Prong		**AM ≤ 3.0 µg/L**	No target; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - C-54 Canal		**AM ≤ 3.0 µg/L**	No target; Applied SJRWMD Target for CIRL North
Taylor Creek Canal		**AM ≤ 3.1 µg/L**	No true target, but spatially included within the SIRL North WBIDs, which are classified as impaired for chlorophyll-a; Applied SJRWMD Target for SIRL North

Tributary Segment	EPA/FDEP	In-House	Comments
St. Lucie River Estuary	**AGM < 5.9 µg/L**		
St. Lucie River Estuary - Manatee Creek	**AGM < 5.9 µg/L**		
St. Lucie River Estuary - Bessey Creek	Narrative	**AGM < 7.4 µg/L**	NNC narrative; Applied EPA/FDEP Target for the St. Lucie Estuary Lower North Fork
St. Lucie River Estuary - Lower North Fork	**AGM < 7.4 µg/L**		
St. Lucie River Estuary - Upper North Fork	**AGM < 6.7 µg/L**		
St. Lucie River Estuary - Lower South Fork	**AGM < 6.7 µg/L**		
St. Lucie River Estuary - Upper South Fork	**AGM < 5.0 µg/L**		
St. Lucie River Estuary - Winding South Fork		**AGM < 5.0 µg/L**	No target; Applied EPA/FDEP Target for Upper South Fork
Loxahatchee River Estuary - Lower Loxahatchee	**AGM < 1.8 µg/L**		
Loxahatchee River Estuary – Middle Loxahatchee	**AGM < 4.0 µg/L**		
Loxahatchee River Estuary - Upper Loxahatchee	**AGM < 5.5 µg/L**		
Loxahatchee River Estuary - Southwest Fork	**AGM < 5.5 µg/L**		
AGM = Annual geometric mean; AAM = Annual arithmetic mean; AM = Annual median			

Total Nitrogen

IRL Proper

There are several established targets for ambient TN concentrations established by the EPA/FDEP, the SJRWMD, and the SFWMD for different regions of the IRL (Table 5). The considerations and metrics used for targets of each sublagoon area are similar to the ones previously described for chlorophyll-a. Targets for the ML were originally established by the EPA/FDEP and confirmed by the ML Reasonable Assurance Plan (Cunningham, 2019). For the BRL, NIRL, and CIRL, available targets from the EPA/FDEP are expressed in loads, while these have been converted to ambient concentrations by the SJRWMD. As with the chlorophyll-a targets, EPA/FDEP uses geometric means as the measure of central tendency, while SJRWMD uses annual medians. After a comparison of the criteria from each source, it was decided that a combination of the established targets would be used in the Indian River Lagoon Ecological Health Assessment (Table 5): the EPA/FDEP targets was used for the ML; the SJRWMD targets for the BRL, CIRL, and NIRL; and the SFWMD target for the SIRL. The rationale behind each selection is identical to that of the chlorophyll-a decision-making process, with the additional rationale of not using the EPA/FDEP targets for the BRL, CIRL, and NIRL as they are measured in loads rather than concentrations. The same revision was made to the selected

EPA/FDEP targets that use annual geometric means, as well as the application of the least conservative SJRWMD target to the entire CIRL.

Table 4. TN targets established by the major sources for specific sublagoon areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Sublagoon Region	EPA/FDEP	SJRWMD Annual	SJRWMD Monthly	SFWMD
ML North	**AGM < 0.51 mg/L**			
ML Central	**AGM < 0.65 mg/L**			
ML South	**AGM < 1.14 mg/L**			
BRL North BRL South	ANLO < 116,314 lbs./year	**AM ≤ 1.32 mg/L**	Wet season median ≤ 1.7 mg/L	
NIRL	ANLO < 189,068 lbs./year	**AM ≤ 1.33 mg/L**	Wet season median ≤ 1.6 mg/L	
CIRL North	ANLO < 684,715 lbs./year	**AM ≤ 0.60 mg/L**		
CIRL South	ANLO < 278,273 lbs./year	**AM ≤ 0.82 mg/L**		
SIRL North	AGM < 0.72 mg/L			**AM ≤ 0.7 mg/L**
SIRL Central	AGM < 0.63 mg/L			
SIRL South	AGM < 0.49 mg/L			

ANLO = Annual Load; AGM = Annual geometric mean; AM = Annual median

IRL Tributaries

For the tributaries, targets created by the EPA/FDEP were considered for the Eau Gallie River, Crane Creek, Goat Creek, the Sebastian River Estuary, St. Lucie River Estuary (all segments with the exception of the Winding South Fork), and Loxahatchee River Estuary (Table 5). Generally, the available site-specific targets for northern and centrally located tributaries are from the EPA/FDEP and expressed in either annual loads (Eau Gallie River and Goat Creek) or specify to use the targets of the closest IRL proper region (Addison Creek, Crane Creek, and the Sebastian River Estuary). For example, the IRL Tributary TMDL document specifies to use the drainage area TN targets of the CIRL for Crane Creek. Big Flounder Creek does not have a site-specific target, however, its WBID is included in the TMDL of the NIRL, which has an EPA/FDEP annual load target. Tributaries located in the southern portion are more site-specific than their northern counterparts. All portions of the North and South Forks (with the exception of the Winding South Fork), have both annual load and annual arithmetic mean targets, the St. Lucie Estuary segment has an annual arithmetic mean target, and Manatee Creek has a long-term average target. All segments of the Loxahatchee River Estuary have annual geometric mean targets. Finally, there are no site-specific TN targets for the remaining tributaries (Turnbull Creek, Horse Creek, Turkey Creek, and Taylor Creek Canal, and the Winding South Fork of the St. Lucie River).

As previously described for the chlorophyll-a target selection, the challenge in establishing TN targets is that the only available ones are EPA which focus on a three-year period exceedance (*i.e.*, exceeding the annual geometric mean more than once in three-year period). Since the Ecological Health Report is examining data annually for comparison purposes, annual target comparisons are required. EPA/FDEP targets were used for the St. Lucie River Estuary (with the exception of a substitution at Manatee Creek and creation of a target for the Winding South Fork) and the Loxahatchee River Estuary as these were site-specific and the only available targets; however, exceedances from the proposed targets would be calculated annually rather than a three-year period, the same method proposed for EPA/FDEP targets of the IRL proper. A substitution was made for the measurement of central tendency at the Manatee Creek; the established target specified for a long-term average, however, this was replaced with the annual arithmetic mean to be consistent with the all other St. Lucie River Estuary segments.

Tributaries whose targets were expressed in annual loads without accompanying flow were replaced with the selected targets of the IRL proper sublagoon region in which the tributary was connected. Tributaries whose TMDL documentation instructed to use the TMDL targets of specific areas of the IRL proper were assigned the selected targets for those sublagoon regions, which was generally the target of either the SJRWMD or SFWMD; the rationale behind this decision was to remain consistent in using annual concentration targets across all parameters as well as ease of assessment as the data are measured in concentrations rather than loads.

For the tributary segments discussed above without targets, the same methodology of chlorophyll-a target selection for these segments was followed by applying the target of the IRL proper sublagoon region in which the tributary directly connected. For example, Turnbull Creek is connected to the NIRL, thus, the SJRWMD annual median target of 1.33 mg/L was applied. The rationale behind this decision being that many of these tributaries are included in the spatial boundaries of either a TMDL or BMAP of the IRL proper segments, thus, they should be covered under their respective targets. Additionally, as there is no target for the Winding South Fork, the same methodology of chlorophyll-a target selection for this segment was followed by applying the target of the closest connected segment (the Upper South Fork of the St. Lucie River).

Table 5. TN targets established by the major sources for specific tributary areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Tributary Segment	EPA/FDEP	In-House	Comments
Turnbull Creek		**AM ≤ 1.33 mg/L**	No target, but covered under the spatial extent of the North IRL BMAP; Assigned SJRWMD NIRL targets
Big Flounder Creek	ANLO < 177,220 lbs./year	**AM ≤ 1.33 mg/L**	No target; WBID included in NIRL TMDL, but no accompanying volume data to calculate the ANLO; Applied SJRWMD Target for NIRL
Addison Creek	Use NIRL TN Target	**AM ≤ 1.33 mg/L**	IRL Tributary document says to use TN targets for the NIRL; Applied SJRWMD Target for NIRL
Horse Creek		**AM ≤ 1.33 mg/L**	No target, but covered under the spatial extent of the NIRL TMDL and BMAP; Applied SJRWMD Target for NIRL
Eau Gallie River	ANLO < 28,842 lbs./year	**AM ≤ 1.33 mg/L**	IRL Tributary TMDL document has annual loading, but no accompanying volume data to calculate concentration; Applied SJRWMD Target for NIRL
Crane Creek	Use CIRL TN Target	**AM ≤ 0.60 mg/L**	IRL Tributary TMDL document says to use TN targets for the CIRL; Applied SJRWMD Target for CIRL North
Turkey Creek		**AM ≤ 0.60 mg/L**	No target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for NIRL
Goat Creek	ANLO < 18,405 lbs./year	**AM ≤ 1.33 mg/L**	Annual loading from TMDL NNC, but no accompanying volume data to calculate

Tributary Segment	EPA/FDEP	In-House	Comments
			concentration; Applied SJRWMD Target for CIRL North
Sebastian River Estuary	● Use CIRL TN Target (ANLO < 962,988 lbs./year) (TMDL) ● ANLO < 323,382 lbs./year (NNC)	**AM ≤ 1.33 mg/L**	IRL Tributary TMDL document and NNC say to use TN targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - North Prong	Use CIRL TN Target (962,988 lbs./year)	**AM ≤ 1.33 mg/L**	IRL Tributary TMDL document says to use TN targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - South Prong	Use CIRL TN Target (962,988 lbs./year)	**AM ≤ 1.33 mg/L**	IRL Tributary TMDL document says to use TN targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - C-54 Canal	Use CIRL TN Target (962,988 lbs./year)	**AM ≤ 1.33 mg/L**	IRL Tributary TMDL document says to use TN targets for the CIRL, but but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Taylor Creek Canal		**AM ≤ 0.7 mg/L**	No target, but spatially included within the SIRL North WBID; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary	**AAM < 0.72 mg/L**	**AAM < 0.72 mg/L**	Replaced LTA with AAM, consistent with the rest of the tributary targets
St. Lucie River Estuary - Manatee Creek	LTA < 0.72 mg/L		
St. Lucie River Estuary - Bessey Creek	**● AAM < 0.72 mg/L (NNC)** ● ANLO < 29,981 lbs./year (TMDL)		
St. Lucie River Estuary - Lower North Fork	**● AAM < 0.72 mg/L (NNC)** ● ANLO < 140,134 lbs./year (TMDL)		
St. Lucie River Estuary - Upper North Fork	**● AAM < 0.72 mg/L (NNC)** ● ANLO < 103,747 lbs./year (TMDL)		
St. Lucie River Estuary - Lower South Fork	**● AAM < 0.72 mg/L (NNC)** ● ANLO < 24,463 lbs./year (TMDL)		
St. Lucie River Estuary - Upper South Fork	**● AAM < 0.72 mg/L (NNC)** ● ANLO < 90, 471 lbs./year (TMDL)		
St. Lucie River Estuary - Winding South Fork		**AAM < 0.72 mg/L**	No target; Applied EPA/FDEP Target for Upper South Fork
Loxahatchee River Estuary - Lower Loxahatchee	**AGM < 0.63 mg/L**		
Loxahatchee River Estuary - Middle Loxahatchee	**AGM < 0.80 mg/L**		
Loxahatchee River Estuary – Upper Loxahatchee	**AGM < 1.26 mg/L**		
Loxahatchee River Estuary - Southwest Fork	**AGM < 1.26 mg/L**		

ANLO = Annual Load; AGM = Annual geometric mean; AAM = Annual arithmetic mean; AM = Annual median

Total Phosphorus

IRL Proper

The available target metrics for total phosphorus are identical to those used for total nitrogen. After a comparison of the criteria from each source, it was decided that a combination of the established targets would be used in the Indian River Lagoon Ecological Health Assessment (

Table 9): the EPA/FDEP targets were used for the ML; the SJRWMD targets for the BRL, CIRL, and NIRL; and the SFWMD target was for the SIRL. The rationale behind each selection is identical to those behind the chlorophyll-a and TN decision-making processes. As with chlorophyll-a and TN, the same revision was made to the selected EPA/FDEP targets, which use annual geometric means, as well as the application of the least conservative SJRWMD target to the entire CIRL.

Table 6. TP targets established by the major sources for specific sublagoon areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Sublagoon Region	EPA/FDEP	SJRWMD		SFWMD
		Annual	Monthly	
ML - North	**AGM < 0.049 mg/L**			
ML - Central	**AGM < 0.048 mg/L**			
ML - South	**AGM < 0.034 mg/L**			
BRL - North	ANLO < 7,825 lbs./year (TMDL)	**AM ≤ 0.029 mg/L**	Wet season median ≤ 0.055 mg/L	
BRL - South	ANLO < 12,181 lbs./year			
NIRL	ANLO < 20,592 lbs./year	**AM ≤ 0.045 mg/L**	Wet season median ≤ 0.08 mg/L	
CIRL - North	ANLO < 111,594 lbs./year	**AM ≤ 0.041 mg/L**		
CIRL - South	ANLO < 53,599 lbs./year	**AM ≤ 0.075 mg/L**		
SIRL - North	AGM < 0.070 mg/L			
SIRL - Central	AGM < 0.060 mg/L			**AGM < 0.070 mg/L**
SIRL - South	AGM < 0.021 mg/L			

ANLO = Annual Load; AGM = Annual geometric mean; AM = Annual median

IRL Tributaries

The available target metrics for total phosphorus are identical to those used for total nitrogen. It was decided the following targets would be used in the Indian River Lagoon Ecological Health Assessment (Table 7): EPA/FDEP targets were used for the St. Lucie River Estuary (with the exception of Manatee Creek and the Winding South Fork) and the Loxahatchee River Estuary; the EPA/FDEP target was used at Manatee Creek with a substitution of the long-term average with the annual arithmetic mean as the measurement of central tendency; tributaries whose targets were expressed in annual loads without accompanying flow were as well as tributaries with no targets were replaced with the selected targets of the IRL proper sublagoon region directly connected to the tributary; and finally, the closest connected tributary segment (the Upper South Fork of the St. Lucie River) was applied to the Winding South Fork of the St. Lucie River Estuary. The rationale behind each selection is identical to those behind the chlorophyll-a and TN decision-making processes. As with chlorophyll-a and TN, the same revision was made to the selected EPA/FDEP targets, which use annual geometric means.

Table 7. TP targets established by the major sources for specific tributary areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment.

Tributary Segment	EPA/FDEP	In-House	Comments
Turnbull Creek		**AM ≤ 0.045 mg/L**	No target, but covered under the spatial extent of the North IRL BMAP; Assigned SJRWMD NIRL targets
Big Flounder Creek	ANLO < 9,320 lbs./year	**AM ≤ 0.045 mg/L**	No target; WBID included in NIRL TMDL, but no accompanying volume data to calculate the ANLO; Applied SJRWMD Target for NIRL
Addison Creek	Use NIRL TN Target	**AM ≤ 0.045 mg/L**	IRL Tributary document indicates to use TN targets for the NIRL; Applied SJRWMD Target for NIRL
Horse Creek		**AM ≤ 0.045 mg/L**	No target, but covered under the spatial extent of the NIRL TMDL and BMAP; Applied SJRWMD Target for NIRL
Eau Gallie River	ANLO < 4,307 lbs./year	**AM ≤ 0.045 mg/L**	IRL Tributary TMDL document includes annual loading, but no accompanying volume data to calculate concentration; Applied SJRWMD Target for NIRL
Crane Creek	Use CIRL TN Target (ANLO < 165,193 lbs./year)	**AM ≤ 0.041**	IRL Tributary TMDL document says to use TN targets for the CIRL; Applied SJRWMD Target for CIRL North
Turkey Creek		**AM ≤ 0.041**	No target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for CIRL North
Goat Creek	ANLO < 3,376 lbs./year	**AM ≤ 0.041**	IRL Tributary TMDL document includes annual loading, but not accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary	● Use CIRL TN Target (ANLO < 165,193 lbs./year) (TMDL) ● ANLO < 63,991 lbs./year (NNC)	**AM ≤ 0.041**	IRL Tributary TMDL document says to use TP targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - North Prong	Use CIRL TN Target (ANLO < 165,193 lbs./year)	**AM ≤ 0.041**	IRL Tributary TMDL document says to use TP targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - South Prong	Use CIRL TN Target (ANLO < 165,193 lbs./year)	**AM ≤ 0.041**	IRL Tributary TMDL document says to use TP targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North
Sebastian River Estuary - C-54 Canal	Use CIRL TN Target (ANLO < 165,193 lbs./year)	**AM ≤ 0.041**	IRL Tributary TMDL document says to use TP targets for the CIRL, but no accompanying volume data to calculate concentration from ANLO; Applied SJRWMD Target for CIRL North

Tributary Segment	EPA/FDEP	In-House	Comments
Taylor Creek Canal		**AGM < 0.070 mg/L**	No target, but spatially included within the SIRL North WBID; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary	**AAM < 0.081 mg/L**		
St. Lucie River Estuary - Manatee Creek	**AAM < 0.081 mg/L**		
St. Lucie River Estuary - Bessey Creek	● **AAM < 0.081 mg/L (NNC)** ● ANLO < 3,373 lbs./year (TMDL)		
St. Lucie River Estuary - Lower North Fork	● **AAM < 0.081 mg/L (NNC)** ● ANLO < 11,672 lbs./year (TMDL)		
St. Lucie River Estuary - Upper North Fork	●**AAM < 0.081 mg/L NNC** ● ANLO < 140,134 lbs./year (TMDL)		
St. Lucie River Estuary - Lower South Fork	● **AAM < 0.081 mg/L (NNC)** ● ANLO < 2,752 lbs./year (TMDL)		
St. Lucie River Estuary - Upper South Fork	● **AAM < 0.081 mg/L (NNC)** ● ANLO < 10,178 lbs./year (TMDL)		
St. Lucie River Estuary - Winding South Fork		**AAM < 0.081 mg/L**	No target; Applied EPA/FDEP Target for Upper South Fork
Loxahatchee River Estuary - Lower Loxahatchee	**AGM < 0.032 mg/L**		
Loxahatchee River Estuary - Middle Loxahatchee	**AGM < 0.030 mg/L**		
Loxahatchee River Estuary – Upper Loxahatchee	**AGM < 0.075 mg/L**		
Loxahatchee River Estuary - Southwest Fork	**AGM < 0.075 mg/L**		

ANLO = Annual Load; AGM = Annual geometric mean; AAM = Annual arithmetic mean; AM = Annual median

Turbidity

IRL Proper

Turbidity targets were established by the EPA/FDEP, SJRWMD, and SFWMD (

Table 9). The EPA/FDEP targets for turbidity were not specific for the IRL and required a good understanding of "natural conditions", which is not available for the IRL, particularly for the different sublagoon areas. After a comparison of the criteria from each source, it was decided that a combination of the established targets would be used in the Indian River Lagoon Ecological Health Assessment (

Table 9): the SFWMD target is to be used for the SIRL and the SJRWMD targets for the BRL, CIRL, and NIRL. The use of the generally applicable EPA/FDEP targets was not chosen as the current background conditions for turbidity are unknown throughout the IRL. Similar to other parameters, SJRWMD had a target for the North and South subsections of the CIRL and these were used as-is by separating our sampling sites by sublagoon region. Additionally, it must be noted that to date, no known turbidity target has been established for the ML. As a result, an in-house target was derived from the target of the closest sublagoon regions, BRL and NIRL, in which the annual median shall not exceed 4 NTU.

Table 8. Turbidity targets established by the major sources for specific areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment

Sublagoon	EPA/FDEP	SJRWMD	SFWMD	In-House
ML	≤ 29 above natural background conditions			**AM <4 NTU**
BRL		**AM < 4 NTU**		
NIRL		**AM < 4 NTU**		
CIRL - North		**AM ≤ 2.5 NTU**		
CIRL - South		**AM ≤ 3.6 NTU**		
SIRL			**AM ≤ 2.84 NTU**	
AM = Annual median				

IRL Tributaries

There are no site-specific turbidity targets that were established for the by IRL tributaries. The EPA/FDEP targets for turbidity were not specific for the tributaries and required a good understanding of "natural conditions", which are also not available. As there were no available targets, it was decided that the same methodology of chlorophyll-a, TN, and TP target selection would be followed by applying the target of the IRL proper sublagoon region in which the tributary directly connected.

Table 9. Turbidity targets established by the major sources for specific tributary areas of the IRL. The bolded targets are those which were selected for use in the Indian River Lagoon Ecological Health Assessment

Tributary Segment	EPA/FDEP	In-House	Comments
Turnbull Creek	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target, but covered under the spatial extent of the North IRL BMAP; Assigned SJRWMD NIRL targets
Big Flounder Creek	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target; WBID is spatially included in NIRL TMDL; Applied SJRWMD Target for NIRL

Tributary Segment	EPA/FDEP	In-House	Comments
Addison Creek	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target, but covered under the spatial extent of the NIRL TMDL; Applied SJRWMD Target for NIRL
Horse Creek	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target, but covered under the spatial extent of the NIRL TMDL and BMAP; Applied SJRWMD Target for NIRL
Eau Gallie River	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target; Applied SJRWMD Target for NIRL
Crane Creek	≤ 29 above natural background conditions	**AM < 4 NTU**	No site-specific target; Applied SJRWMD Target for NIRL
Turkey Creek	≤ 29 above natural background conditions	**AM ≤ 2.5 NTU**	No site-specific target; Applied SJRWMD Target for CIRL North
Goat Creek	≤ 29 above natural background conditions	**AM ≤ 2.5 NTU**	No site-specific target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for CIRL North to be consistent with other parameters
Sebastian River Estuary	≤ 29 above natural background conditions	**AM ≤ 2.5 NTU**	No site-specific target, but covered under the spatial extent of the CIRL North TMDL; Applied SJRWMD Target for CIRL North to be consistent with other parameters
Sebastian River North Prong			No site-specific target; Applied SJRWMD Target for CIRL North
Sebastian River South Prong			No site-specific target; Applied SJRWMD Target for CIRL North
Sebastian River C-54 Canal			No site-specific target; Applied SJRWMD Target for CIRL North
Taylor Creek Canal	≤ 29 above natural background conditions	**AM ≤ 2.84 NTU**	No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary	≤ 29 above natural background conditions	**AM ≤ 2.84 NTU**	No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Manatee Creek			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Bessey Creek			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Lower North Fork			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Upper North Fork			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Lower South Fork			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Upper South Fork			No site-specific target; Applied SJRWMD Target for SIRL North
St. Lucie River Estuary Winding South Fork			No site-specific target; Applied SJRWMD Target for SIRL North
Lower Loxahatchee	≤ 29 above natural background conditions	**AM ≤ 2.84 NTU**	No site-specific target; Applied SJRWMD Target for SIRL South
Middle Loxahatchee			No site-specific target; Applied SJRWMD Target for SIRL South
Upper Loxahatchee			No site-specific target; Applied SJRWMD Target for SIRL South

Tributary Segment	EPA/FDEP	In-House	Comments
Loxahatchee Southwest Fork			No site-specific target; Applied SJRWMD Target for SIRL South
AM = Annual median			

Testing the Ecological Water Quality Health Indicators

Offset Calculations and Establishment Class Breakpoints

After the comparison and selection of targets, it was necessary to establish a method of relating each water quality parameter with its target. This relationship was dependent on the metric used by the target and the distribution of the water quality data. In regards to the parameters selected for the IRL Ecological Health Assessment, the desired condition is to remain below the selected target, thus, offsets from the established target were used to categorize results. This allowed for the comparison of the results to be performed at the sublagoon area level rather than a subsection of each sublagoon. Offsets are calculated as follows:

$$Offset = Target - Result\ Value$$

Each parameter was graded using a custom scale associated with its offset data. Breakpoints for the scales were created using the frequency distributions of the offsets of both the IRL proper and tributary data combined, following a modified Jenks classification type. The classification including setting five breakpoints using a normal distribution (Jenks) with the exception of ensuring that one of the classes represented meeting the target (*e.g.*, a zero offset value). The resulting scale is a color system with six classes, four negative offset classes (below target) and two positive offset classes (meeting or exceeding target). This process was performed for each individual station, and also regionally for the sublagoon regions or tributary segments. Regional offsets were calculated by averaging the offset of stations assigned to a particular IRL Proper region or tributary segment, ultimately ending with the same classification system of four negative offset classes and two positive offset classes.

Chlorophyll-a

Chlorophyll-a targets are maximum annual medians or geometric means requiring that data be at or below the target to meet the requirements. Chlorophyll-a offsets established for each target by year and for the initial period of record (1996-2016) are positive if they meet or are lower than the target and negative if they exceed the target concentration. The central tendencies (median and geometric mean) were calculated for each station from time-series data using Minitab 19 software and a custom Python script for each individual year as well as the POR. The central tendency data were placed into a customized Microsoft Access database that was created for the scoring process. A series of queries were created to assign targets and calculate the offset from the regional targets provided in Table 2 and Table 3 based on the location of each station. Data were summarized by averaging offsets of each sublagoon region or tributary segment for each year and for the entire POR.

Offset data ranged from < -60 µg/L to > 10 µg/L, meaning in some years, the actual data exceeded the target by more than 60 µg/L and in others the annual data were 10 µg/L or more below the target. The frequency distribution of the data, as shown in Figure 7, provided guidance to create the classes to be used in the chlorophyll-a gradient (Table 10). Breakpoints were selected by a combination of methods: natural breaks (attempt to distribute the data frequency equally for all the classes) and manually. Manual breakpoints were always required to ensure a class was created to clearly identify sites that are meeting the target and comfortably exceeding the target. Four additional classes were distributed to indicate data just barely not meeting the desired target versus three well below target classes (which were guided by the data distribution).

Table 10. Class gradients chosen for chlorophyll-a based on the frequency distribution of the data.

Classes
≤ (-10.000)
> (-10.000) to (-3.000)
> (-3.000) to (-1.000)
> (-1.000) to < 0.000
0 to < 1.000
≥ 1.000

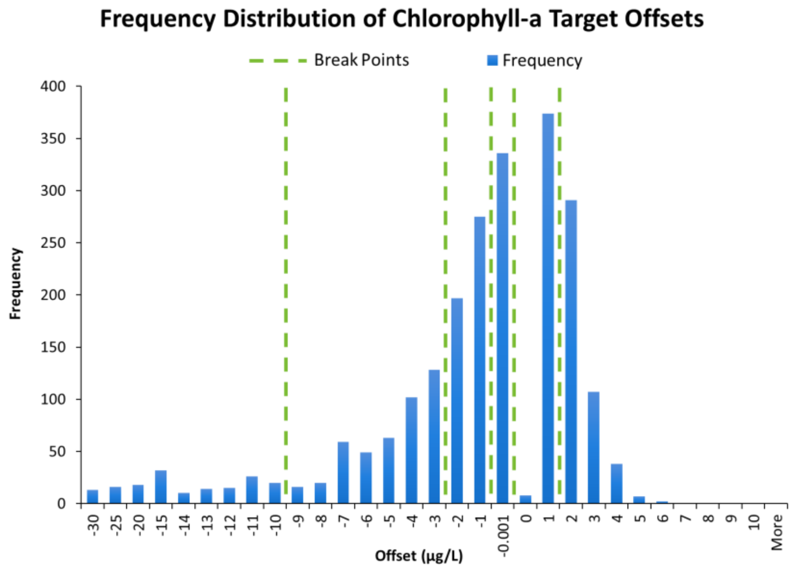

Figure 7. Histogram of chlorophyll-a offset values.

Total Nitrogen

TN had site-specific targets that used annual medians, arithmetic means, and geometric means. The results are reported in offsets from the established target by year and the initial POR (1996-2016) for each sublagoon region or tributary segment. As with chlorophyll-a, central tendencies (median, arithmetic mean,

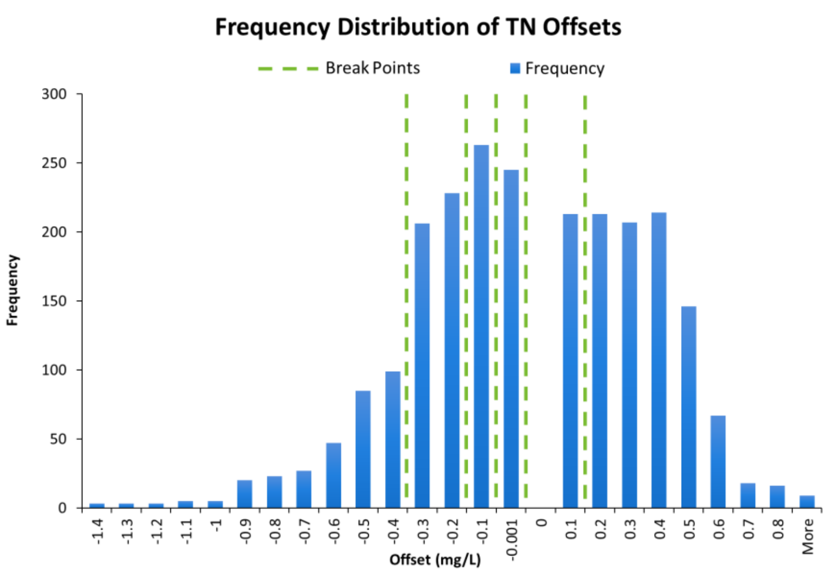

Table 11. Class gradients chosen for TN based on the frequency distribution of the data.

Classes
≤ (-0.400)
> (-0.400) to (-0.200)
> (-0.200) to (-0.100)
> (-0.100) to < 0.000
0 to < 0.200
≥ 0.200

Figure 8. Histogram of TN offset values.

and geometric mean) for each station were calculated from time-series data for each individual year as well as the POR and offsets from the respective regional targets (Table 4 and Table 5). Microsoft Access queries were created to assign targets based on the spatial location of the monitoring stations and calculate the offset from the targets. Offset data ranged from < -2.0 µg/L to > 0.9 µg/L, and the distribution of this data provided guidance to create the classes to be used in the TN gradient (Figure 8, Table 11).

Total Phosphorus

Similar to TN, TP had site-specific targets that used medians, arithmetic means, and geometric means, and the results are reported as offsets from the established target by year and the initial POR (1996-2016) for each sublagoon region and tributary segment. The central tendencies (median, arithmetic mean, and geometric mean) for each station were calculated from time-series data for each individual year as well as the POR. Offsets from the target data (provided in Table 6 and Table 7) were calculated from the central tendency data per year and for the POR. TP offsets ranged from < -0.30 mg/L and >0.09 mg/L. The frequency distribution of the data, as shown in Figure 9, provided guidance to create the classes to be used in the TP gradient (Table 12).

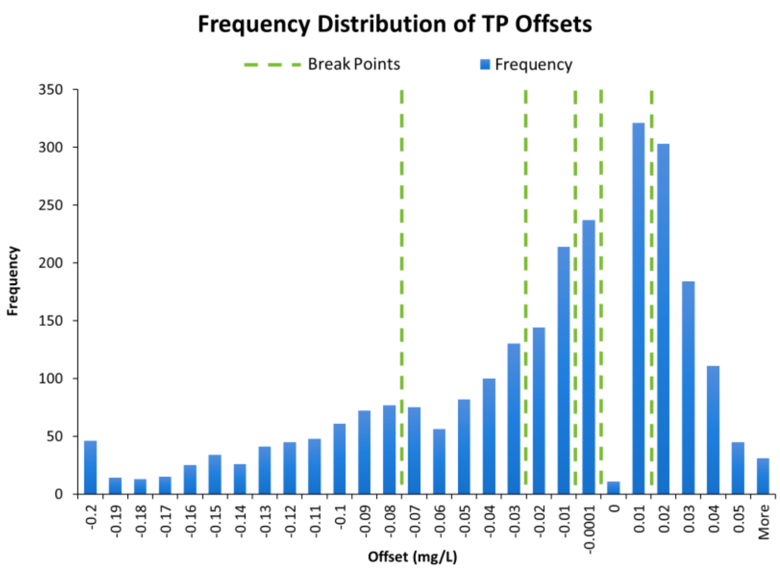

Figure 9. Histogram of TP offset values.

Table 12. Class gradients chosen for TP based on the frequency distribution of the data.

Classes
≤ (-0.080)
> (-0.080) to (-0.030)
> (-0.030) to (-0.010)
> (-0.010) to < 0.000
0 to < 0.010
≥ 0.010

Turbidity

Turbidity had site-specific targets that used annual medians. Results are reported in offsets from the established target summarized by year and for the initial POR (1996-2016). Once annual and POR medians were calculated per site, queries were created in Microsoft Access to assign targets based on the spatial location of the monitoring stations as well as calculate the number of records below the minimum targets provided in Table 8 and

Table 9. Offsets for turbidity ranged from <75 NTU to >2 NTU. The frequency distribution of the data, as shown in Figure 10, provided guidance to create the classes to be used in the turbidity gradient (Table 13).

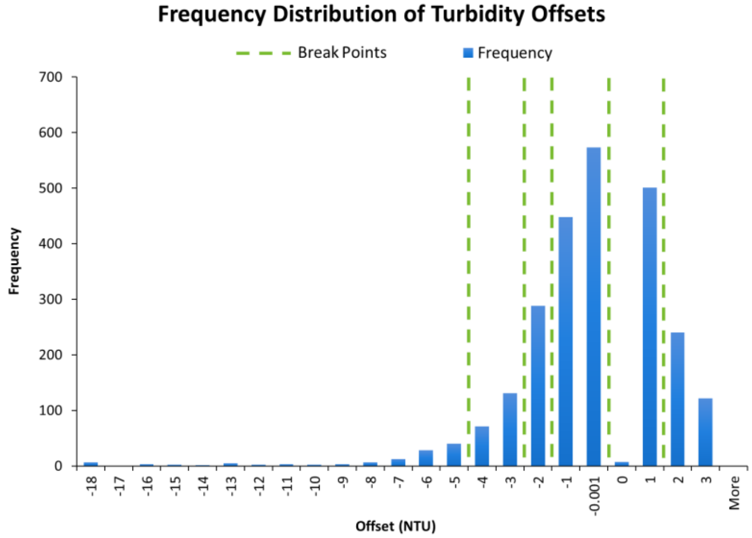

Figure 10. Histogram of turbidity offset data.

Table 13. Class gradients chosen for turbidity based on the frequency distribution of the data.

Classes
≤ (- 5.000)
> (-5.000) to (-3.000)
> (-3.000 to (-2.000)
> (-2.000) to < 0.000
0.000 to < 1.000
≥ 1.000

Water Quality Health Scoring Systems

The target measurements discussed above were used in the final scoring process for the 2016 year (first year of the reporting effort). Two scoring systems were used to grade water quality indicators by sublagoon area: (1) a Water Quality Index (WQI) which was created in-house, and (2) a Trophic State Index (TSI) created by FDEP in 1996 (http://www.tampabay.wateratlas.usf.edu/shared/learnmore.asp?toolsection=lm_tsi). Scoring was performed for each sublagoon region or tributary segment; however, there were specific instances within the St. Lucie River Estuary that combined particular segments together (Table 14). The specific indicators and how they are used within each index are discussed below.

Table 14. Scoring regions of each sublagoon region and tributary segment.

Sublagoon/Tributary	Sublagoon Region/Tributary Segment	Scoring Region
ML	ML North	ML North
	ML Central	ML Central
	ML South	ML South
BRL	BRL	BRL
NIRL	NIRL	NIRL
CIRL	CIRL North	CIRL North
	CIRL South	CIRL South
SIRL	SIRL North	SIRL North
	SIRL Central	SIRL Central
	SIRL South	SIRL South
Turnbull Creek	Turnbull Creek	Turnbull Creek
Big Flounder Creek	Big Flounder Creek	Big Flounder Creek
Addison Creek	Addison Creek	Addison Creek
Horse Creek	Horse Creek	Horse Creek
Eau Gallie River	Eau Gallie River	Eau Gallie River
Crane Creek	Crane Creek	Crane Creek
Turkey Creek	Turkey Creek	Turkey Creek
Goat Creek	Goat Creek	Goat Creek
Sebastian River Estuary	Sebastian River Estuary	Sebastian River Estuary
	Sebastian River North Prong	Sebastian River North Prong
	Sebastian River South Prong	Sebastian River South Prong
	Sebastian River C-54 Canal	Sebastian River C-54 Canal
Taylor Creek Canal	Taylor Creek Canal	Taylor Creek Canal
St. Lucie River Estuary	St. Lucie River Estuary St. Lucie River Estuary Manatee Creek	St. Lucie River Estuary
	St. Lucie River Estuary Bessey Creek	St. Lucie River Estuary Bessey Creek
	St. Lucie River Estuary Lower North Fork St. Lucie River Estuary Upper North Fork	St. Lucie River Estuary North Fork
	St. Lucie River Estuary Lower South Fork St. Lucie River Estuary Upper South Fork	St. Lucie River Estuary South Fork
	St. Lucie River Estuary Winding South Fork	St. Lucie River Estuary Winding South Fork
Loxahatchee River Estuary	Lower Loxahatchee	Lower Loxahatchee
	Middle Loxahatchee	Middle Loxahatchee
	Upper Loxahatchee	Upper Loxahatchee
	Loxahatchee Southwest Fork	Loxahatchee Southwest Fork

Water Quality Index (WQI):

The WQI utilizes four water quality indicators with well-established site-specific targets: chlorophyll-a, TN, TP, and turbidity. The WQI results are calculated for the individual regions of each sublagoon area by converting annual offsets to a numeric scale, resulting in a final score ranging from 0 to 100. Individual parameters were subjected to this process, then averaged together with equal weight:

$$WQI = \frac{[(Chlorophyll - a\ Score) + (TN\ Score) + (TP\ Score)\ + (Turbidity\ Score)\ ]}{4}$$

Equal weighing of parameters to develop indices followed the guidance and methods provided by the UMCES - IAN during discussions about indicators and methods that took place at the Science Assembly and typically used in several well-established report cards (Chesapeake Bay, Coastal Bays, Long Island Sound, Coastal Georgia, among others; UMCES - IAN 2015a, UMCES - IAN 2015b).

As the offset data breakpoints were not distributed at equal intervals, custom conversion formulas were created for each of the classes defined in the previous section. The resulting scale was divided into six classes (0 to 49, 50 to 59, 60 to 69, 70 to 79, 80 to 89, and 90 to 100), which allowed for easy association to a single offset class. The tail ends of each offset scale were stretched 10% beyond the current minima and maxima to ensure future values would be incorporated, with the exception of stretching the range would be incompatible with the logical scale. If future data are below the current negative offset extreme, the lowest score (0) will automatically be assigned; if the future data are above the current positive offset extreme, the highest score (100) will automatically be assigned. The conversion formulas use a ratio of the ranges from both class systems, a normalizing value, and a conversion factor to achieve a final score for each parameter.

This process was performed on individual stations as well as sublagoon regions and tributary segments to calculate annual scores for each parameter and the combined WQI. Results for sublagoon regions and tributary segments were rounded to whole numbers and placed into tables and color-coded based on the established gradient to aid visual interpretation. Additionally, individual stations and sublagoon region and tributary segments were mapped using the same color scale with the associated regional scores displayed next to each area.

During the temporal and spatial expansions of the dataset (reporting years 2017-2019), some alterations in the methodology became necessary. The first alteration was applied to the scoring systems of the tributary (initiating in reporting year 2017). Although the IRL proper and tributary data followed very similar distribution patterns and shared the identical breakpoints for each class, the extrema (minimum and maximum) offset values were distinct between the IRL Proper and tributaries for scoring systems of some parameters. In other words, the extrema used in the scoring systems of the IRL Proper are representative of the minimum and maximum offset values of the stations located in the IRL Proper for the original POR, and the extrema used in the tributary scoring systems were generally representative of stations located in the tributaries. This was done to ensure the offsets and scores of the tributaries were not dampened by restricting the scoring system to the bounds of the IRL Proper as conditions in water quality are quite different between the two as a result of hydrological factors (flow, residence time, etc.).

The second change from the original methodology is related to the calculation of the WQI. During the second reporting year (year 2017), there were six stations (five in the NIRL and one in the Eau Gallie River) that did not have quarterly turbidity data. It was decided the WQI would be calculated with the omission of a turbidity score for these stations. The rationale behind this being that turbidity has lesser sensitivity that the other indicators for these stations, thus, omitting it from the WQI calculations had little effect on the overall score. Furthermore, as there are already so few stations to represent each sublagoon region, specifically the Eau Gallie River, it was decided that removing these stations would also remove pertinent, informative data that helps tell the story of those regions.

Example WQI Calculation

This section will be used to demonstrate the process of calculating the WQI using the 2016 regional data for the CIRL South. As the WQI is a combination of four water quality parameters, the process will first demonstrate how the chlorophyll-a score is calculated from the regional offset. Table 15 demonstrates the association between the two class systems (offsets and scores).

Table 15. Association between offset and percentage score classes of the IRL Proper sublagoon regions.

Offset Classes (µg/L)	Chlorophyll-a Score Classes	Category
≤ (-10.000)	0 – 49.999	Extremely Poor
> (-10.000) – (-3.000)	50 – 59.999	Very Poor
> (-3.000) – (-1.000)	60 – 69.999	Poor
> (-1.000) – (-0.000)	70 – 79.999	Average
0 – < 1.000	80 – 89.999	Good
≥ 1.000	90 – 100	Very Good

The ranges for each class were found by calculating the difference between the minimum and maximum values. During the development of this scoring system using data within the original POR (1996-2016), the average offsets for chlorophyll-a in the entire IRL system ranged from -27.86 ug/L to 2.06 ug/L (Table 16). As previously stated, these extrema were stretched by 10% during the initial assessment in 2016 to ensure the inclusion of future offsets that could potentially extend outside the current datasets boundaries.

Table 16. Calculation of the chlorophyll-a score.

Offset Classes Extrema (µg/L)	Extended Extrema (+ 10%)	Offset Range	Score Classes	Score Range	Normalizer	Range Ratio
(-27.860) – (-10.000)	-30.650	20.65	0 – 49.999	49.999	30.650	2.421
(-9.999) – (-3.000)		6.999	50 – 59.999	9.999	9.999	1.429
(-2.999) – (-1.000)		1.999	60 – 69.999	9.999	2.999	5.002
(-0.999) – (-0.001)		0.998	70 – 79.999	9.999	0.999	10.019
0 – 0.999		0.999	80 – 89.999	9.999	0.000	10.009
1.000 – 2.060	2.263	1.263	90 – 100	10.000	-1.000	7.916

The 2016 CIRL South offset was -1.231 µg/L, which would fall into the 60 - 69.999 chlorophyll-a score class. To calculate the final score for the given parameter, the normalizer (the absolute value of the class minima) is first added to the offset value, then multiplied by the ratio, and finally the minima of the offset score class (60) is added to the overall result. This process is demonstrated below:

$$2016\ Chlorophyll - a\ Score = (Offset + Normalizer)\ x\ Ratio + Offset\ Score\ Class\ Minima$$

$$2016\ Chlorophyll - a\ Score = (-1.231 + 2.999)\ x\ 5.002 + 60 = 68.842$$

As previously stated, this process was repeated independently for each indicator. This ensures that all four indicators used in the WQI were normalized from a 0-100 scale, which always indicates from poor-great ecological scores based on target offsets. The final WQI averaged the normalized indicator values and assumed equal weight to all four variables.

The following equations demonstrate the final WQI calculation for the CIRL South:

$$WQI_{CIRL\ South} = \frac{[(Chlorophyll - a\ Score) + (TN\ Score) + (TP\ Score)\ + (Turbidity\ Score)\ ]}{4}$$

$$WQI_{CIRL\ South} = \frac{[68.842 + 92.665 + 64.276 + 87.998]}{4} = 78.445$$

Trophic State Index (TSI):

The TSI was originally developed by FDEP in 1996 to classify productivity in lake and estuary systems and only incorporates three indicators: chlorophyll-a, TN, and TP. Individual TSI values are first calculated from the raw annual central tendency values specific to the sublagoon area of a particular indicator (*e.g.,* median or geometric mean) using the equations below:

$$TSI_{(Chlorophyll-a)} = 16.8 + [14.4\ x\ \ln(annual\ chlorophyll - a)]$$

$$TSI_{(TN)} = 56.0 + 19.8\ x \ln(annual\ TN)$$

$$TSI_{(TP)} = 18.6\ x\ [\ln(annual\ TP\ x\ 1000)] - 18.4$$

After individual TSI values were calculated, they were combined to achieve the final TSI score using the following equation for "Nutrient-Balanced Lakes (10 ≤ TN/TP ≥30)":

$$TSI = \left\{TSI_{(chlorophyll-a)} + \frac{[TSI_{(TN)} +\ TSI_{(TP)}]}{2}\right\} / \ 2$$

The final TSI values have values ranging between 0-100 range, with 0-49 corresponding to a "good" TSI, the 50-59 to as "fair" TSI, and the 60-100 to a "poor" TSI value.

Example TSI Calculation

For comparison purposes, data for the CIRL South during 2016 will be used to calculate the TSI score below:

$$TSI_{(Chlorophyll-a)} = 16.8 + [14.4\ x\ \ln(4.83134)] = \ 39.48178$$

$$TSI_{(TN)} = 56.0 + 19.8\ x \ln(0.50767) = \ 42.57698$$

$$TSI_{(TP)} = 18.6\ x\ [\ln(0.09588\ x\ 1000)] - 18.4 = \ 66.47264$$

$$TSI = \left\{39.48178 + \frac{[42.57698 +\ 66.47264]}{2}\right\} /2 = \ 47.00330$$

Indices Comparison

We recommend the use of the WQI for the IRL Ecological Health Assessment since it was developed by integrating site-specific targets for each sublagoon region and tributary segment. The TSI is a great tool to classify estuaries (and lakes) based on nutrient concentrations and chlorophyll values for which no site-specific targets have been developed. The TSI is more a measure of the potential for algal and aquatic weed growth than a measure of ecological health based on water quality. The WQI includes turbidity as an additional indicator which is important to understand changes in the Lagoon's health, not always captured by chlorophyll-a measurements. Finally, the WQI provides numbers that can be interpreted in 6 classes (0-49, 50-59, 60-69, 70-79, 80-89, and 90-100), similar to a grading scale, easier to communicate to the public. The TSI provides a similar 0-100 range, but it classifies this in three broad classes (0-49, 50-59, and 60-100), with a less intuitive interpretation. For example, the lowest class (0-49) corresponds to a "good" TSI, the mid-narrow range (50-59) as "fair", and the highest class (60-100) corresponds to a "poor" TSI value. Furthermore, the differences in the class ranges may exaggerate the overall health of the system. As demonstrated above with the CIRL South in 2016, the resulting TSI score (47.003) would be categorized as a "good" value, while the WQI of (78.445) would classify this region within the WQI "Average" category.

HABITAT INDICATORS

Data Acquisition

SJRWMD provided seagrass transect survey information. This included spatial locations, the maximum length of deep edge distances, and TMDL target distances for seagrass transects. Seagrass survey data for each transect was collected during the summer months from 1994-2019. The data obtained for the transects were received as points, which were spaced in 1-m increments along the total length of the transect.

Data Processing

Seagrass transect data were converted to polylines and centroid points for ease of visualization. During the first year, each transect was assigned to a sublagoon and sublagoon region using spatial analyses. Investigation into the spatial representation of seagrass transects in the tributaries was initiated during the second year, as this was one of the major goals. There are eight active transects that are situated within the St. Lucie and Loxahatchee River Estuaries; however, there is no monitoring within any other tributary. Due to the lack of spatial representation across the IRL system, it was decided that the tributaries would not be incorporated into the habitat index; the eight transects would keep their previous spatial assignments of the IRL proper sublagoon regions Tabular data were related to the transect data by a unique transect identifier. No additional processing was required before testing the data against the established target (see "Testing the Ecological Habitat Health Indicators" section).

Establishing Targets for Relevant Ecological Habitat Indicators

For the development of the methodology report, the emphasis was on indicators with well-established targets. TMDL target distances for the maximum deep edge of seagrass transects were provided by SJRWMD. Even though there are 100 established and monitored transects, three of these transects (Transect 2, 79, and 82) were located in either the ML or in the SIRL and have no available TMDL targets. Data from these three sites could not be used in the target development and offset analysis. Additionally, five transects have been dropped over the years due to site inaccessibility (7, 68, 78, 80, 97). Furthermore, in recent years three transects (site 65 in the SIRL North and sites 69 and 86 in the SIRL Central) have been composed entirely of *Halophila sp.* and do not have any other canopy forming seagrass species. As the *Halophila* species have ephemeral tendencies, resulting in highly variable distribution, it was decided that these transects would be assigned a zero score during the habitat quality analysis.

Testing the Ecological Habitat Health Indicators

General Methodology

Similar to the water quality indicators, it was necessary to establish a method of consistently comparing the annual data for each habitat indicator against its established target. For seagrass transects, the offsets from an established numerical target (transect length in meters), were calculated in percentage offsets using the following formula:

$$Percent\ Offset\ = \left(\frac{Result\ Value - Target}{Target}\right) x\ 100$$

Negative values always indicate that the selected target has not been met, while positive results consistently convey that the targets were either met or exceeded.

Results for each transect were summarized by year, sounded to the nearest whole number, and reported in a color-coded tabular format to aid visual interpretation. The frequency distribution of the offset data for the initial POR (1994-2016), provided guidance to create the classes to be used in the seagrass transect gradient (Figure 11,Table 17). Classes in the green ranges meet or exceed the transect length targets, while yellow-red shades indicate values below the established targets.

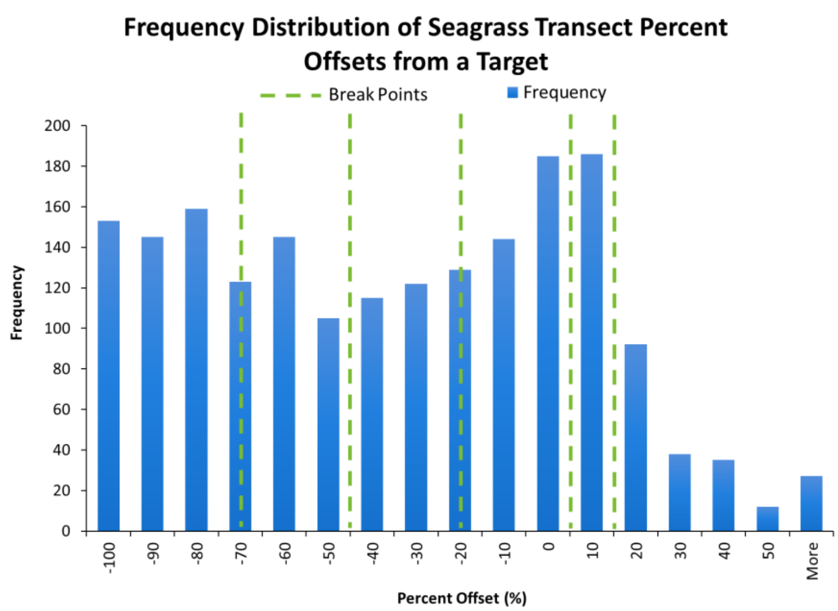

Figure 11. Histogram of seagrass transect length percent offsets.

Table 17. Class gradients chosen for seagrass transect length based on the frequency distribution of the data

Classes
≤ (-75.000)
> (-75.000) to (-50.000)
> (-50.000) to (-25.000)
> (-25.000) to < 0.000
0 to < 10.000
≥ 10.000

As with the WQI, the data were further summarized to achieve the mean annual percent offset value of each sublagoon region. This was done by averaging the percent offsets of transects located within each sublagoon region. Individual transect and regional annual offsets were converted to a score from 0-100 (discussed in the section below). The results for sublagoon regions were placed into tables and color-coded based on the established gradient to aid visual interpretation. Additionally, individual transects and sublagoon regions were mapped using the same color scale with the associated sublagoon scores displayed next to each area.

Habitat Index

A habitat index was developed to normalize the offset percentages from the seagrass transect data to a 0-100 scale, identical to the previously described Water Quality Index scale. Establishing a habitat index allows future indicators to be incorporated into the index using the same normalized approach. It also simplifies communication with the public by providing indices with the same scale range and interpretation for both water quality and habitat.

As the offset data breakpoints for transect length were not distributed at equal intervals, custom conversion formulas were created for each of the classes defined in the previous section. The final scale was divided into six classes (0 to 49, 50 to 59, 60 to 69, 70 to 79, 80 to 89, and 90 to 100), which allowed for easy association to a single offset class. The positive tail end of the offset scale (for values exceeding target values) were stretched to ensure future values would be incorporated. The negative tail of the data distribution has values incorporating the logical minimum of the transect offset data (100% loss of transect length) and did not need to be stretched. The conversion formulas use a ratio of the ranges from both class systems, a normalizing value, and a conversion factor to achieve a final score. The conversion between the percent offset transect values and final habitat index classes is provided in Table 18.

Table 18. Association between transect length offset and habitat index classes.

Transect Offset Classes (%)	Habitat Index Score Classes
≤ (-75.000)	0 – 49.999
> (-75.000) to (-50.000)	50 – 59.999
> (-50.000) to (-25.000)	60 – 69.999
> (-25.000) to < 0.000	70 – 79.999
0 to <10.000	80 – 89.999
≥ 10.000	90 – 100

Conclusions and Future Recommendations

The initial development of a “State of the Lagoon” report required extensive data compilation, quality assurance, and analysis efforts to ensure appropriate metrics are defined. This Methodology Report provides a synthesis of critical information, including the establishment of appropriate targets, offset analyses, and the development of a site-specific water quality and habitat indices, for the selected metrics. The focus of this report is twofold: 1) water quality indicators, which have well-accepted regulatory targets and, in most cases, a dense network of data for the past 22 years (1996-current) and 2) habitat indicators that are available for the entire spatial extent of the Lagoon and historic-current. Two peer-review meetings took place with members of the IRL NEP STEM Peer Review committee to discuss indicator selection, data cleaning, and offset analysis focused on water quality and habitat indicators. The methods described herein allow the report to be easily updated and expanded as new data are collected and received.

The process of developing an Ecological Health Assessment is adaptive and additional metrics are expected to be included as additional targets for extensively available datasets (*e.g.,* fisheries data) are developed and agreed upon by the scientific community. Socioeconomic, land development, and behavioral metrics could also be included when expanding an ecological health assessment to a more global “Status Report”. The focus for this methodology report, however, has been on describing the most scientifically valid indicators selected for the ecological health assessment, including sublagoon or region-based targets, methods to test against these, and the development of normalized indices that communicate spatial and temporal changes to the public.

Several indicators that appear initially as robust and key indicators were eliminated through the analysis process as methodology standards and spatiotemporal coverage were tested. These included fecal coliform, dissolved oxygen, seagrass areal extent and wetland coverage targets. We opted to generate two indices (a Water Quality Index and a Habitat Index) that use the most extensive and reliable datasets available for the past 22 years across most of the Indian River Lagoon. The water quality index uses the same variables as the Trophic State Index or TSI (Chlorophyll-a, TN, TP) and adds turbidity, as a measure of water clarity, so critical for the ecological health of the Lagoon. However, the developed WQI incorporates site-specific criteria for each of the parameters of interest by spatial region, unlike the TSI, which uses ambient concentration values and generalized formulas applied to any estuary in the US. Understanding the complexity and variability of the conditions within the IRL estuary, as well as their associated ecological targets, highlights the importance of using site-specific information when applying a grade to each region. Additionally, having a dataset that spans over 20 years to provides a more reliable, robust, and comparable index for the Ecological Health Assessment.

The habitat index uses a similar range (0-100) and includes only the annual transect length offsets from well-established site-specific TMDL targets. This index is prepared to allow future variables to be included, such as wetland areal extent.

Target and respective offset analyses have indicated the existence of gaps that might need to have additional dedicated funding and/or staffing:

- datasets for several water quality indicators have been progressively reduced in recent years, both by reducing the sampling stations and, in some cases, sampling frequency; ensuring that no other stations are decommissioned, and frequency is, at least, maintained is critical to ensure the future assessments of the IRL ecosystem;
- for many stations, not enough data were present to represent the interannual variability of that specific indicator (*e.g.,* not enough data were provided for the 2016 wet season for fecal coliform);
- specific sublagoon regions had limited to no data stations with available data; this is particularly obvious for the southern region of the SIRL, which has no had a WQI score since 2012;
- current sampling methods do not provide adequate data to allow a reliable analysis of target offsets, (*e.g.,* dissolved oxygen minimum or monthly average targets, HAB ambient monitoring)
- fecal coliforms monitoring is typically performed in non-stationary locations and in an inconsistent time interval, with higher frequency as a responsive management strategy; adding static monitoring locations using consistent time intervals and units of measurements every month would greatly enhance the analytical capabilities; furthermore, adding *Enterococci* to the monitoring network might provide a direct indicator of human health risk;

- establishing site-specific targets for smaller tributaries that has significant impact on the Lagoon, such as Turkey Creek
- establishing targets for appropriate salinity ranges for a broader area of the Lagoon;
- establishing targets for several wildlife indicators;
- establishing targets for appropriate abundance of select fish species of concern, ecological, recreational or/and commercial value.

In Year 2 of the reporting effort (Year 2017), twelve tributaries were added to the ecological health assessment. Year 3 of the reporting period included the analysis of 2018 and 2019 data without any additional changes in methodology. We anticipate expanding the ecological health assessment in subsequent years to include additional indicators of interest, as adequeate targets are established or identified.

References

America's Watershed Initiative. (2015). *America's Watershed Initiative Report Card for the Mississippi River: Methods report on data sources, calculations, additional discussion*. Retrieved from the Missouri Coalition for the Environment website: http://www.moenvironment.org/files/Large_Rivers/Mississippi-River-Report-Card-Methods-v10.1-With%20Destinations.pdf.

Conservancy of Southwest Florida. (2011). *Conservancy of Southwest Florida's 2011 Estuaries Report Card*. Retrieved from the Conservancy of Southwest Florida website: https://www.conservancy.org/document.doc?id=379.

Costanzo, S., Kelsey, H., & Saxby, T. (2015). *Willamette River Report Card 2015: Scores and Scoring Methodology*. Retrieved from the University of Maryland Center for Environmental Science Eco Health Report Cards website: https://ecoreportcard.org/site/assets/files/1426/2015-willamette-methods-report.pdf.

Crean, D.J., Robbins, R.M., & Iricanin, N. (2007). Water quality target development in the Southern Indian River Lagoon. *Florida Scientist, 70* (4), 522–531.

Cunningham, B.A. (2019). Mosquito Lagoon Reasonable Assurance Plan (RAP). Gainesville, FL: Jones Edmunds & Associates, Inc. and Janicki Environmental, Inc. for Volusia County and the Mosquito Lagoon RAP Stakeholder Group.

Dale, V. H., & Beyeler, S. C. (2001). Challenges in the development and use of ecological indicators. *Ecological Indicators, 1* (1), 3-10. doi: http://dx.doi.org.portal.lib.fit.edu/10.1016/S1470-160X(01)00003-6

Environmental Protection Agency. (2015). *Chapter 62-302: Surface water quality standards*. Retrieved from the Environmental Protection Agency website: https://www.epa.gov/sites/production/files/2014-12/documents/fl_section62-302.pdf.

Fla. Admin. Code ch. 62, § 304.520. Indian River Lagoon TMDLs. 2013.

Fla. Admin. Code ch. 62, § 304.705. St. Lucie Basin TMDLs. 2012.

Fla. Admin. Code ch. 62, § 304.710. Loxahatchee Basin TMDLs. 2012.

Feng, Y., Ling, L., Yanfeng, L., You, Z., Musong, C., & Xigang, X. (2015) A dynamic water quality index model based on functional data analysis. *Ecological Indicators, 57,* 249–258.

Gao, X. (2009). *TMDL Report: Indian River Lagoon and Banana River Lagoon, Nutrients and DO, March 2009*. Tallahassee, FL: Florida Department of Environmental Protection Division of Environmental Assessment and Restoration.

Gao, X. (2013). *Final TMDL Report: Nutrient TMDL for Goat Creek Marine Segment (WBID 3107A)*. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration.

Gao, X, & Rhew, K. (2013). *TMDL Report: Dissolved Oxygen and Nutrient TMDLs for Eight Tributary Segments of the Indian River Lagoon*. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration.

Gilbert, R.O. (1987). *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold Co., New York, NY. 320 pp.

Hamel, N., *et al.* (2015). *2015 State of the Sound: Report on the Puget Sound Vital Signs*. Retrieved from the Puget Sound Partnership website: https://pspwa.app.box.com/v/2015-SOS-vitalsigns-report.

Heink, U., & Kowarik, I. (2010). What are indicators? On the definition of indicators in ecology and environmental planning. *Ecological Indicators, 10*(3), 584-593. doi:http://dx.doi.org.portal.lib.fit.edu/10.1016/j.ecolind.2009.09.009

Hou, W., Sun, S., Wang, M., Li, X., Zhang, N., Xin, X., Sun, L., Li, W., & Jia, R. (2016). Assessing water quality of five typical reservoirs in lower reaches of Yellow River, China: Using a water quality index method. *Ecological Indicators, 61,* 309–316.

Hirsch, R.M., Slack, J.R., & Smith, R.A. (1982). Techniques of trend analysis for monthly water quality data. *Water Resources Research, 18,* 107–121.

Hirsch, R.M., and Slack, J.R. (1984). A nonparametric trend test for seasonal data with serial dependence. *Water Resources Research, 20,* 727–732.

Integration & Application Network at the University of Maryland Center for Environmental Science. (2015). *Long Island Sound: Grading the Water Quality and Ecosystem Health of the Urban Sea.* Retrieved from the University of Maryland Center for Environmental Science website: https://ecoreportcard.org/site/assets/files/1853/2016-long-island-sound-report-card.pdf.

Integration and Application Network, University of Maryland Center for Environmental Science. (2015). *The Development Process and Methods for the Coastal Georgia Report Card*. Retrieved from the Coastal Georgia Departments of Natural Resources website: http://coastalgadnr.org/sites/uploads/crd/images/ReportCard/Coastal_Georgia_Report_Card_White_Paper.pdf.

Jha, D.K., Devi, M.P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N.V. & Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. *Marine Pollution Bulletin, 100,* 555–561.

Kurtz, J. C., Jackson, L. E., & Fisher, W. S. (2001). Strategies for evaluating indicators based on guidelines from the environmental protection Agency's office of research and development. *Ecological Indicators, 1*(1), 49-60. doi: http://dx.doi.org.portal.lib.fit.edu/10.1016/S1470-160X(01)00004-8

Macauley, J. M., Summers, J. K., Engle, V. D., & Harwell, L. C. (2002). The ecological condition of South Florida estuaries. *Environmental Monitoring and Assessment, 75*(3), 253-269.

Mann, H.B. (1945). Nonparametric tests against trend. *Econometrica, 13,* 245-259.

Niemeijer, D. & de Groot, R.S. (2008) A conceptual framework for selecting environmental indicator sets. *Ecological Indicators, 8,* 14-25. doi: 10.1016/j.ecolind.2006.11.012

Parmer, K., Laskis, K., McTear, R., & Peets, R. (2008). *TMDL Report: Nutrient and Dissolved Oxygen TMDL for the St. Lucie Basin*. Tallahassee, FL: Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management.

Paulic, M., Hand, J., and Lord, L. Florida Department of Environmental Protection. (1996). 1996 Water-Quality Assessment for the State of Florida Section 305(B) Main Report. Tallahassee, FL: Bureau of Water Resources Protection, Division of Water Facilities, Florida Department of Environmental Protection.

Steward, J.S., Lasi, M.A., & Phlips, E.J. (2010). *Using multiple lines of evidence for developing numeric nutrient criteria for Indian River and Banana River lagoons, Florida*. Palatka, FL: St. John's River Water Management District.

Steward, J.S.,Virnstein, R.W., Morris, L.J., & Lowe, E.F. (2005). Setting seagrass depth, coverage, and light targets for the Indian River Lagoon system, Florida. *Estuaries, 28* (6), 923-935.

Turnhout, E., Hisschemöller, M., & Eijsackers, H. (2007). Ecological indicators: Between the two fires of science and policy. *Ecological Indicators, 7*(2), 215-228. doi:http://dx.doi.org.portal.lib.fit.edu/10.1016/j.ecolind.2005.12.003

Tyler, D. (2008). *TMDL Report: Fecal Coliform TMDL for Eau Gallie River, WBID 3082*. Tallahassee, FL: Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management.

Wanda, E. M.M., Mamba, B. B. & Msagati, T.A.M. (2016). Determination of the water quality index ratings of water in the Mpumalanga and North West provinces, South Africa. *Physics and Chemistry of the Earth, 92,* 70 -78. http://dx.doi.org/10.1016/j.pce.2015.09.009

White, G. & Turner, J. (2012). *TMDL Report: Fecal Coliform TMDL for Southwest Fork Loxahatchee River WBID 3226C*. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration.

Williams, M., Longstaff, B., Buchanan, C., Llano, R., & Bergstrom, P. (2007). *Development of an Integrated and Spatially Explicit Index of Chesapeake Bay Health (Bay Habitat Health Index - BHHI)*. Retrieved from the University of Maryland Center for Environmental Science website: https://ian.umces.edu/pdfs/supporting_analysis_tech_doc.pdf.