

Status of Town of Dennis Freshwater Ponds 2001-2015 Water Quality Database Development

FINAL REPORT

October 2016

for the

Town of Dennis



Prepared by:

Coastal Systems Group
School for Marine Science and Technology
University of Massachusetts Dartmouth
706 South Rodney French Blvd.
New Bedford, MA 02744-1221



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Prepared By

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Cover photo: Fresh Pond (September, 2016)

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I. Introduction

The Town of Dennis, like much of Cape Cod, has numerous ponds and lakes scattered throughout the town. According to the Cape Cod Pond and Lake Atlas, Dennis has 57 ponds covering a total area of 275 acres (Eichner and others, 2003). Of these ponds, 30 are greater than one acre and six are classified as great ponds (>10 ac). Over the course of the last ten years, local concerns about the water quality of Dennis's ponds have often become focused by algal blooms, fish kills, and concerns related to the impacts from population growth.

Assessment and management of these pond resources has evolved slowly, but recently has become more focused with greater interest in coordinated water quality management for all the aquatic resources that share the aquifer lenses of Cape Cod. Any ponds greater than 10 acres are classified as "Great Ponds" under Massachusetts law and are publicly-owned waters.¹ This concept was developed prior to the creation of the United States, during the governance of the Massachusetts Bay Colony.² Federal laws protecting surface water quality were reaffirmed and strengthened in 1972 with the passage of the Clean Water Act.³ The Clean Water Act includes a concept of determining acceptable contaminant loads, otherwise known as Total Maximum Daily Loads (TMDLs). Under the provisions of the Act, water quality standards in state regulations determine whether a water body is impaired and all impaired water bodies must have a TMDL for the contaminant causing the impairment. In 1988, residents of all 15 towns on Cape Cod approved the creation of the Cape Cod Commission, which eventually led to the creation of an integrated water quality management strategy⁴ that included all water resources including ponds. In 2000, Cape Cod pond resources moved closer to active assessment and management with the creation of the Cape Cod Pond and Lake Stewards (PALS) program. PALS activities included the production of the Cape Cod Pond and Lake Atlas, which contained the first complete list of all ponds on Cape Cod (nearly 1,000 ponds), and the first PALS water quality snapshot.⁵ The first PALS snapshot included volunteers from all 15 Cape Cod towns collecting over 400 water quality samples at more than 190 ponds. The Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) provided logistical, laboratory analysis and project management services at no cost to the towns or volunteers and the results were used in the Cape Cod Pond and Lake Atlas to complete a regional overview of pond water quality. CSP/SMAST has continued the PALS Program and to provide the needed services for every PALS Snapshot through 2016. Many of the Cape towns, including Dennis, have funded technical reviews of the PALS water quality data and have used the data as the baseline for more refined assessments and/or development of water quality management strategies for individual ponds.

¹ MGL c. 91 § 35

² Heather J. Wilson, The Public Trust Doctrine in Massachusetts Land Law, 11 B.C. Env'tl. Aff. L. Rev. 839 (1984), <http://lawdigitalcommons.bc.edu/ealr/vol11/iss4/6>

³ 33 U.S.C. §1251 *et seq.*

⁴ Eichner, EM. 1993. Watershed protection: A Cape Cod perspective on national efforts. *Environmental Science and Technology* 27, no. 9: 1736—1740.

⁵ Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

The Town of Dennis last completed a review of town-wide pond water quality seven years ago.⁶ Aside from reviewing 2001-2008 data for all the ponds, the 2009 Dennis Ponds Report also included more refined data review and synthesis, identification of data gaps, and management next steps for 6 ponds selected by the Town. The more refined data review included delineation of watersheds, development of water budgets, and phosphorus budgets. These preliminary steps toward development of management strategies provided analysis of the conditions of the ponds and which data gaps were major roadblocks for development of management strategies and goals.

The Town WQAC followed up on the 2009 Dennis Ponds Report by prioritizing the resulting recommendations for action. They began by asking CSP/SMAST to collect information to fill the key data gaps for Scargo Lake⁷ and Fresh and Cedar ponds.⁸ The WQAC then followed the development of the new data for Scargo Lake with the development of a management plan for the lake.⁹

The 2009 Ponds Report also identified data gaps that existed for most of the ponds: lack of bathymetry, identification of stormwater systems near ponds, and sampling of stormwater for ponds if they were identified as impaired. It also recommended that the Town: a) continue pond water quality sampling with two samplings per year (April and August/September) in order to understand seasonal influences and year-to-year fluctuations, b) complete more detailed review of the 5 other ponds with water quality data, and c) determine the regulatory status for the 6 ponds that had received detailed reviews. Determining the regulatory status would be clarifying with the Massachusetts Department of Environmental Protection (MassDEP) whether the ponds identified as impaired in the 2009 Report would be listed by MassDEP as impaired and, thus, would be required to have TMDLs under the provisions of the Clean Water Act).

This current report expands on the 2009 report and reviews all the Dennis Ponds water quality data collected between 2001 and 2015 for the 11 ponds regularly sampled through the town Water Quality Advisory Committee (Figure I-1). All PALS Snapshot results and any available supplementary data were synthesized, including all data collected since the 2009 Ponds Report. The current review has allowed CSP/SMAST project team to prepare a unified database of all the available pond data, including a review of statistics, identification of outliers, and assessment of trends. This dataset was then reviewed pond-by-pond to prepare recommendations for individual ponds and for consideration in developing Town-wide strategies for pond management.

⁶ Eichner, E. 2009. Dennis Freshwater Ponds: Water Quality Status and Recommendations for Future Activities. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 106 pp.

⁷ CSP/SMAST Technical Memorandum. February 23, 2012. Scargo Lake Technical Support Project. To: Virginia Esau, Chair, Water Quality Advisory Committee and Karen Johnson, Director of Natural Resources, Town of Dennis. From: Ed Eichner and Brian Howes.

⁸ CSP/SMAST Technical Memorandum. December 18, 2012. Eagle Pond and Cedar Pond Technical Support Project: Bathymetry, Submerged Aquatic Vegetation and Mussel Surveys, Water Bird Survey. To: Suzanne Brock, Chair, Water Quality Advisory Committee and Karen Johnson, Director of Natural Resources, Town of Dennis. From: Ed Eichner, Brian Howes, and David Schlezinger.

⁹ Eichner, E., B. Howes, and D. Schlezinger. 2012. Scargo Lake Water Quality Management Report. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 65 pp.

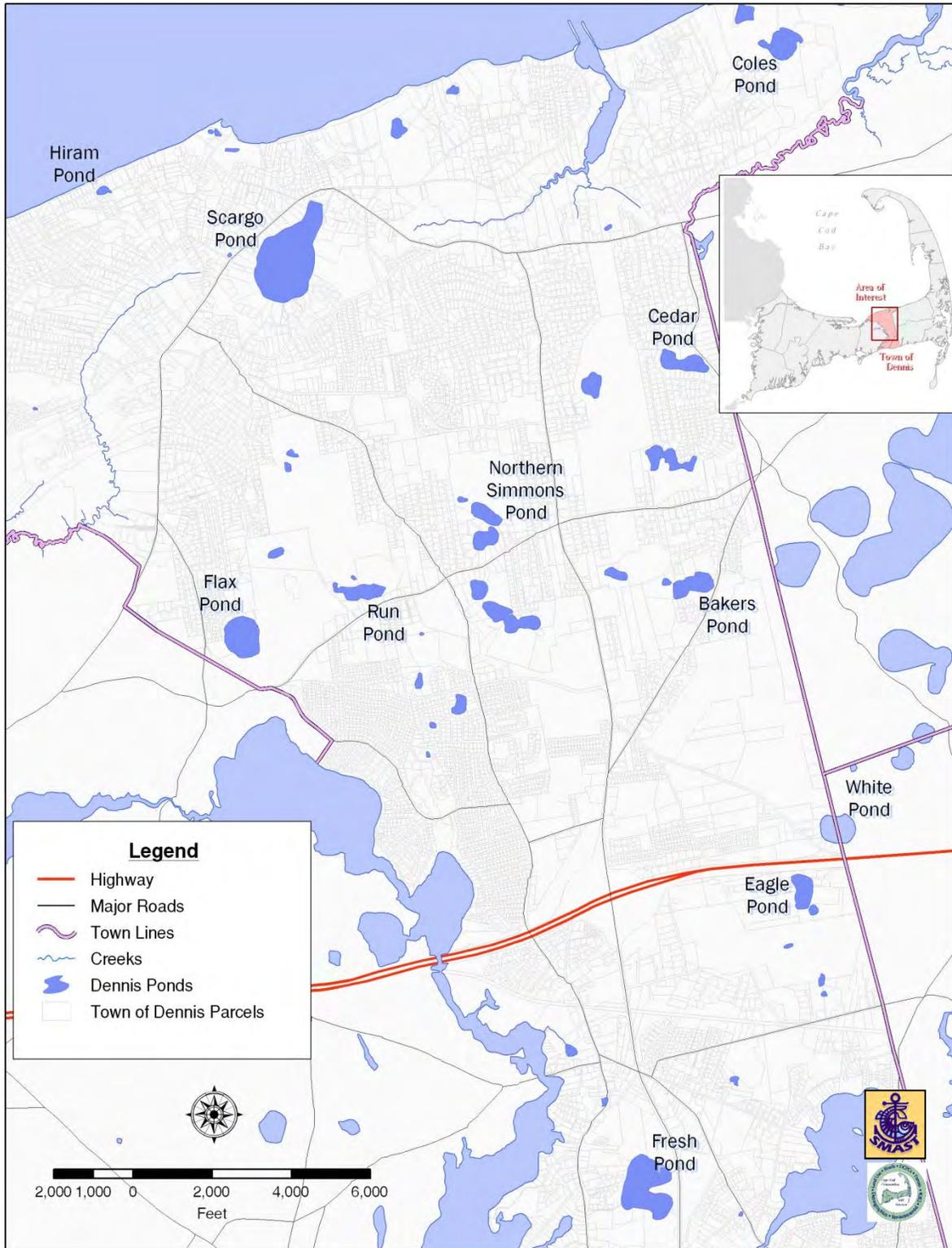


Figure I-1. Ponds regularly sampled by Dennis volunteers

The 11 ponds with name labels have been regularly sampled by Dennis volunteers and their water quality information is reviewed in this report. The Town of Dennis has a total of 57 ponds (Eichner and others, 2003).

II. Pond Data Sources

Project staff have collected and organized available pond water quality data (Table II-1). Available datasets included PALS Snapshot data from 2001 to 2015, enhanced 2011 Scargo Lake water quality data, and town-funded collection of April water quality samples. Both PALS Snapshot and the April samples were assayed at the CSP/SMAST Analytical Facility using the same procedures consistently used during assays of all PALS Snapshot samples; these procedures have been approved by MassDEP and USEPA for PALS parameters. There is also a dataset of laboratory data from 2002 and 2003 that was assayed at the Cape Cod National Seashore lab.

Water quality samples analyzed at the CSP/SMAST Analytical Facility used analysis and sampling procedures in the MassDEP-approved SMAST Coastal Systems Analytical Facility Laboratory Quality Assurance Plan (2003). These procedures, which are used for all 15 years of PALS Snapshot samples, include analysis of the following parameters: total nitrogen, total phosphorus, chlorophyll-*a*, pH, and alkalinity. The laboratory services through the CCNS were limited to available grant funding during 2002 and 2003.

Organization of the available data found that the variety of datasets needed to be brought into a consistent format; column order was often different from year to year even among the PALS data, reporting units differed between the labs, and pond names often differed slightly from year to year (e.g., “White Pond” vs. “Whites Pond” vs. “White’s Pond” vs. “Whites”). This formatting consistency step also found and corrected some data input mistakes: data transpositions (e.g., dissolved oxygen and temperature profiles transposed). All available data was brought into a consistent format for later review and analysis.

Collection, handling and transport of samples and assay of each parameter generally followed PALS Snapshot protocols. PALS

protocols call for collection of samples based on the depth of the pond. All ponds have a minimum of two samples collected. Shallow ponds less than 1.5 m deep have two samples collected just below the surface (0.5 m depth). Ponds up to 9 m deep have a shallow sample collected at 0.5 m depth and a deep sample 1 m above the bottom. Ponds greater than 10 m deep have four samples collected: 0.5 m, 3 m, 9 m, and one meter above the bottom. Water samples are collected as whole water, stored at 4°C, and transferred to the SMAST lab within 24 hours. In addition to the collection of samples, measurements of dissolved oxygen (DO), temperature, clarity/Secchi depth, and station depth are collected. Temperature and DO profiles are generally recorded at 1 m increments after the 0.5 m measurement (i.e., 0.5 m, 1 m, 2 m, etc.). Profiles in

year	PALS	April	CCNSS
2001	X		
2002	X		X
2003	X		X
2004	X		
2005	X		
2006	X		
2007	X		
2008	X	X	
2009	X	X	
2010	X	X	
2011	X	X	
2012	X	X	
2013	X	X	
2014	X	X	
2015	X	X	

ponds shallower than 3 m are recommended for 0.5 m increments. Volunteers are trained/briefed by PALS “captains” that have been trained in sampling techniques and have PALS Snapshot experience. These PALS captains organize the town volunteers, oversee sharing of equipment, etc.; in Dennis, the WQAC ensures volunteers follow PALS sampling protocols.

The PALS Snapshot was designed to collect samples during the period when water quality is likely to be at its worst (*i.e.*, between August 15 and the end of September). This period was initially targeted as a way to find out which of the ponds had impaired water quality and use that information to prioritize the development of management options and to guide collection of more refined supplementary data. These field sampling strategies have been used by Dennis volunteers and those in other towns to conduct sampling outside of the PALS Snapshot period to develop expanded summer-long results or sampling during April/May to evaluate seasonal changes. Use of consistent PALS sampling protocols has allowed all the data to be compared regardless of the season when it is collected.

III. Review of Individual Ponds

The current water quality for each pond is briefly discussed below based on the cumulative dataset developed during this project. Presented review is based on the whole dataset minus outliers, review of shallow and deep groups, and review of seasonal water quality (April/May/Spring and August/September/Summer). Outliers were generally infrequent with one or two samples identified. There were, however, selected categories that had notably more frequent outliers: deep samples and pH readings.

The deepest sample in each sampling run was assessed to determine if the deep basin was actually sampled. Deep samples are supposed to be collected 1 m above the bottom at the deepest location in the pond. Occasionally, samplers missed the deepest location and collected samples at a significantly shallower depth. Significantly shallower samples can obscure real differences in seasonal or year-to-year changes. Any deep samples that were shallower than the average station depth minus two standard deviations were included in the overall pond dataset, but were not included in the comparison of shallow and deep results. The number of deeper samples not include in the deep averages are listed for each individual ponds below and generally represent 10-15% of the sampling runs.

Readings for pH also had frequent outliers. pH readings are determined by the interaction hydrogen ions with carbon species, like carbon dioxide, carbonate, and bicarbonate, having the most direct effect. Photosynthesis takes carbon dioxide and hydrogen ions out of the water causing pH to increase, so more productive lakes will tend to have higher pH measurements. The pH of rainwater, in equilibrium with carbon dioxide in the atmosphere, is 5.65 and the Cape Cod groundwater that feeds the ponds is generally close to this reading because there are few carbonate materials in the sandy soils that make up the Cape. During mostly 2005, a frequent number of very low pH readings (2 to 3) were included in town water quality records; typically 8-10% of the individual pond datasets. Most of these readings were removed during the outlier analysis.

Review of the individual pond datasets focused on comparisons to available numeric Massachusetts Department of Environmental Protection (MassDEP) surface water regulatory

standards¹⁰ and Cape Cod-specific guidelines previously developed from PALS data.¹¹ Time-series graphs of dissolved oxygen, temperature, chlorophyll, total phosphorus, and total nitrogen at shallow and deep depths are included in Appendix A for each pond. Discussion of the data results also includes recommendations for subsequent targeted data collection to support management decisions and develop pond-specific management strategies.

¹⁰ Massachusetts surface water standards are included in 314 CMR 4. Massachusetts standards include both numeric limits and descriptive goals for various categories based on their use (e.g., for drinking water or recreational use) or their characteristics (e.g., salt vs. fresh water).

¹¹ Cape Cod-specific pond water quality guideline concentrations were developed using the results of the first PALS Snapshot and are included in the Cape Cod Pond and Lake Atlas (Eichner and others, 2003).

III.A. Bakers Pond

Bakers Pond is a 10 acre pond that is located to the west of Airline Road with a delineated watershed completed for the 2009 Dennis Ponds Report. It has an occasional connection to another small pond at its western end and has a largely undeveloped shoreline. Review of historic aerial photography suggests that it has an extensive macrophyte/rooted plant community.

Average water depth at the water quality sampling station was 4.57 m (n=56). There were 7 sampling runs when samplers missed the deep sampling location (*i.e.*, maximum depth shallower than two standard deviations from the mean/average depth). Secchi/clarity readings did not vary significantly by season with average readings of 4.4 m and 95% of the water column depth.

Temperature and dissolved oxygen (DO) profile data show that the pond is generally well-mixed throughout its water column with no significant difference between shallow and deep averages a) overall, b) in April/May (spring) and c) in August/September (summer). Only 3 of the 207 DO readings (1%) are less than the MassDEP minimum (5 mg/L). Average August/September DO concentrations are significantly lower than April/May, while corresponding temperature readings are significantly higher. Average summer DO saturation levels are significantly lower (83% shallow and 75% deep) than spring averages suggesting that water column and sediment oxygen demand is greater than oxygen inputs to bottom waters from summer photosynthesis. Average summer chlorophyll concentrations are significantly higher (~2X) than spring concentrations, but are generally lower than the Cape Cod guidance limit (1.7 µg/L).

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Bakers Pond. As would be expected in a well-mixed pond where plant production is limited by available phosphorus, total nitrogen concentration averages were generally the same (0.36-0.37 mg/L) at all depths and both seasons. Total phosphorus concentrations are not statistically different in the summer and winter, although concentrations are generally lower during the summer, which suggests that macrophytes may play an important role in pond's water quality.

Recommendation/Summary

Bakers Pond management largely depends on the Town's specific uses and resource quality objectives. Water quality in the pond does not show any signs of significant impairment, although the lower oxygen during the summer may portend future water quality decline and therefore is something to continue to watch. Water clarity is good. Chlorophyll and total phosphorus are generally low (also good). Review of the TP and chlorophyll data do show occasional high spikes likely related to low oxygen releasing phosphorus from the sediments, but these are infrequent. Time-series review of the data shows no significant trends. The apparent large macrophyte community appears to be having an important impact on the water quality data, but planning for controls on this community should largely depend on whether these are interfering with desired uses of the pond. The 2009 Dennis Ponds Report recommended a low-level maintenance sampling program for Bakers Pond with April and August/September sampling that follows PALS protocols. This recommendation still holds unless there are additional pond use concerns.

If more extensive management is pursued, the following data gaps need to be addressed: a) bathymetric map, b) evaluation of the stream/transitory connection to the small pond to the west, c) evaluation of summer sediments and/or dissolved oxygen to understand the low summer oxygen and its relation to phosphorus “spikes”, and d) evaluation of stormwater runoff from Airline Road, if any. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

Table III-1. Bakers Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	4.68			4.93		4.49		<	
N	52			13		20			
Max	5.40			5.34		5.02			
Min	4.00			4.38		4.00			
Secchi Depth									
Average (m)	4.40			4.56		4.32			
N	52			13		20			
Max	5.20			5.20		5.02			
Min	3.38			3.65		3.79			
Temperature									
Average (°C)	20.04	20.49	19.12	15.00	14.36	23.68	23.39	>	>
N	229	55	34	14	11	20	10		
Max	27.41	27.41	27.20	17.20	16.40	27.40	26.70		
Min	10.60	12.30	10.60	12.30	12.00	19.40	19.20		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.08	8.25	8.31	10.03	10.12	7.03	6.38	<	<
N	200	50	29	11	9	19	9		
Max	11.85	10.85	11.85	10.85	11.76	8.68	9.17		
Min	2.74	5.43	2.74	9.21	8.24	5.43	2.74		
N < 5 mg/L DO	3	0	2	0	0	0	1		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	6.09	6.05	6.11	6.26	6.20	6.22	6.29		
N	91	42	21	11	9	20	10		
N < 6.5 pH	82	38	18	9	8	18	8		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	1.16	1.03	1.15	0.63	0.64	1.25	1.54	>	>
N	47	23	16	8	7	15	9		
Max	3.02	2.36	3.00	0.84	0.85	2.36	3.00		
Min	0.03	0.03	0.35	0.42	0.35	0.03	0.42		
N > 1.7 µg/L	10	3	3	0	0	3	3		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	10.60	10.76	8.77	12.34	9.02	8.39	7.92		
N	68	35	17	10	8	20	8		
Max	27.00	27.00	15.76	27.00	15.76	14.25	13.01		
Min	0.77	1.55	0.77	1.86	1.68	1.55	0.77		
N > 10 µg/L	33	15	8	6	4	5	3		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.36	0.36	0.36	0.37	0.36	0.36	0.36		
N	67	34	18	9	8	20	10		
Max	0.53	0.53	0.48	0.48	0.41	0.53	0.48		
Min	0.18	0.20	0.26	0.20	0.31	0.20	0.26		
N > 0.32 mg/L	49	24	14	8	7	13	7		

III.B. Cedar Pond

Cedar Pond is a 9 acre pond that is located to the west of Airline Road and north of Indian Field Drive with a delineated watershed completed in the 2009 Dennis Ponds Report. It has an extensive associated freshwater wetland along the majority of the northern shoreline that is occasionally inundated during periods of higher groundwater levels. The pond has extensive development along its southern shoreline and historic aerial photography suggests that the pond bottom has an extensive macrophyte/rooted plant community.

Average depth of the water quality sampling station was 3.82 m (n=56) with a small but statistically significant difference between spring and summer average depths (3.94 m and 3.71 m, respectively). There were 10 sampling runs when samplers missed the deep sampling location (*i.e.*, maximum depth shallower than two standard deviations from the mean/average depth). Secchi/clarity readings did not vary significantly by season with overall average readings of 1.93 m and 51% of the water column.

Temperature profile data show that shallow and deep average temperatures are significantly different year-round, including the spring and summer. This finding is somewhat surprising for such a shallow pond, but may be a function of the high topography which surrounds most of the pond or some sort of hydrogeologic control consistently discharging deeper, colder groundwater. Average dissolved oxygen concentrations have a similar pattern. Of the 183 DO readings, 43 (23%) are less than the MassDEP minimum (5 mg/L). More than half of the DO readings less than the MassDEP minimum are at depths shallower than 2.5 m, which means that low DO concentrations exist throughout the water column, not just in waters closest to the sediments. During the summer, waters closest to the sediments average less than 5 mg/L and the degree of depletion is enhanced by the long periods of temperature stratification.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Cedar Pond. The ratio is higher in the summer, primarily due to a few occasions where total phosphorus concentrations were low. These occasions also had high chlorophyll to total pigment ratio, suggesting that these were blooms that were measured. Average summer surface chlorophyll concentrations are significantly higher (~3X) than spring concentrations with both summer and spring average higher than the Cape Cod guidance limit (1.7 µg/L). Similarly, shallow and deep total phosphorus average concentrations (overall, spring, and summer) are higher than the Cape Cod guidance concentration (10 µg/L) with persistent significant differences between shallow and deep averages, which would also be consistent with the stratification and sediment regeneration. Average shallow and deep total nitrogen concentrations are also significantly different, but there is no significant change with the seasons.

Recommendation/Summary

Cedar Pond is impaired based on: a) its failing to meet MassDEP DO minimums during the summer and b) its high chlorophyll and total phosphorus concentrations well above Cape Cod guidance levels. Its average diminished clarity reinforces these impairments. Cedar Pond is not listed in any capacity in the most recent MassDEP Integrated List, but this may be due to its size (9 acres) being less than the Great Pond 10 acre threshold.

In 2012, the Town began to move forward to address data gaps necessary to prepare a water quality management plan for Cedar Pond.¹² The CSP/SMAST technical team completed a survey of submerged vegetation and freshwater mussels, collected bathymetry, and synthesized WQAC volunteer bird counts. This information found that Cedar Pond had a) a pond volume 41% smaller than indicated by the previous bathymetry, b) that freshwater mussels were not present in the pond, c) that aquatic plants were extensive throughout most of the pond with bottom coverage of 75% or more throughout most of the pond, and d) confirmed the mass of pond-specific phosphorus loading from birds. At the time, CSP/SMAST recommended that if the Town wished to move forward with a water quality management plan of Cedar Pond, it should address the following remaining data gaps: 1) measure the stormwater flows and phosphorus loads from the 7 direct discharge sites identified by town volunteers in the 2009 Ponds Report, 2) collect and incubate sediment cores to measure sediment release of phosphorus, and 3) combine and synthesize all of the available information to develop a restoration plan for Cedar Pond. These recommendations are still relevant and are reinforced by the current review. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

¹² CSP/SMAST Technical Memorandum. December 18, 2012. Eagle Pond and Cedar Pond Technical Support Project.

Table III-2. Cedar Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	3.82			3.94		3.71		<	
N	56			15		20			
Max	4.38			4.30		4.25			
Min	3.10			3.20		3.10			
Secchi Depth									
Average (m)	1.93			2.13		2.09			
N	56			15		21			
Max	3.54			3.54		3.00			
Min	0.59			1.00		0.59			
Temperature									
Average (°C)	18.54	19.86	15.07	15.60	11.91	22.65	18.74	>	>
N	184	54	26	14	10	21	9		
Max	27.20	27.20	24.00	18.70	14.30	27.20	24.00		
Min	8.20	8.70	8.70	11.12	8.70	18.40	15.53		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	6.74	7.62	5.01	9.29	8.27	6.69	3.25	<	<
N	183	53	27	13	9	21	9		
Max	12.31	12.15	9.70	10.40	9.70	8.68	6.43		
Min	1.18	3.98	0.08	8.50	6.68	4.21	0.36		
N < 5 mg/L DO	43	7	12	0	0	4	6		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	5.52	5.60	5.24	5.82	5.38	5.67	5.80		
N	89	41	20	11	7	19	7		
N < 6.5 pH	89	41	20	11	7	19	7		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	12.69	5.11	27.22	2.22	7.94	6.30	38.24	>	
N	48	24	11	7	4	17	7		
Max	106.81	14.17	106.81	3.90	11.76	14.17	106.81		
Min	0.80	0.80	1.83	0.80	2.83	1.58	1.83		
N > 1.7 µg/L	44	21	11	5	4	16	7		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	24.09	19.82	34.36	19.54	35.36	19.78	32.39		
N	68	35	13	9	5	19	6		
Max	67.90	35.98	67.90	35.42	48.32	35.98	67.90		
Min	0.77	0.77	9.32	0.77	20.51	6.19	9.32		
N > 10 µg/L	64	32	12	8	5	17	5		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.52	0.47	0.65	0.48	0.62	0.45	0.63		
N	68	35	13	10	5	18	7		
Max	1.13	0.87	0.96	0.75	0.96	0.63	0.95		
Min	0.29	0.30	0.41	0.34	0.45	0.30	0.41		
N > 0.32 mg/L	64	32	13	10	5	16	7		

III.C. Coles Pond

Coles Pond is an 11-acre shallow Great Pond that is located in the northeast portion of Dennis, east of Coles Pond Road and approximately 250 m from Cape Cod Bay. It is in an area that is sparsely developed and it has associated freshwater wetlands located to its north and west, including a smaller pond that appears to have a hydroconnection to Coles Pond. Much of its southern shoreline is part of Town's Crowes Pasture Conservation Area. Pond water quality was reviewed, along with a delineation of its watershed, in the 2009 Dennis Ponds Report.

Average depth of the water quality sampling station was 1.43 m (n=53) with a statistically significant difference between spring and summer average depths (1.60 m and 1.31 m, respectively). Maximum recorded depth was 2 m. Given the shallow depth of the pond, samplers occasionally collected two surface (0.5 m) samples rather than collecting a deep sample; this occurred during 7 of 53 sampling runs. Secchi/clarity readings did not vary significantly by season with overall average readings of 1.26 m and 90% of the water column.

With such a shallow depth, it would be expected that the water column would have similar temperatures near the surface and near the sediments and there is no statistical difference in the shallow and deep averages in the overall data record, spring records, or summer records. Also as expected, the pond is very responsive to seasonal temperature cycles with summer averages (22.53°C and 22.67°C, shallow and deep) being significantly higher than spring averages (14.21°C and 13.74°C, shallow and deep). Average dissolved oxygen concentrations have a similar pattern, though summer DO saturation levels are significantly less than atmospheric equilibrium (*e.g.*, summer shallow waters average 86% saturation). This depression in DO levels is due to sediment oxygen demand in excess of photosynthetic additions. Given its shallow depth, it would be reasonable to assume that DO levels during the summer would be near atmospheric equilibrium (100% saturation). Although summer DO levels are depressed (indicative of high sediment oxygen uptake), none of the 93 DO readings are less than the MassDEP minimum (5 mg/L), though minima of less than 6 mg/L were recorded at both shallow and deep stations. It is likely that DO is maintained in the summer through inputs from the atmosphere which can mask significant oxygen depletion in very shallow ponds.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Coles Pond. Average summer surface chlorophyll concentrations are significantly higher (~7X) than spring concentrations with only summer averages (both shallow and deep) higher than the Cape Cod guidance limit (1.7 µg/L). More than half (58%) of all the collected surface chlorophyll concentrations exceed the Cape Cod guidance limit and some of the readings suggest that samples were collected during or shortly after significant blooms (*i.e.*, concentrations 8-10X the guidance limit). The same relationship does not exist for total phosphorus with no significant difference between spring and summer averages or shallow and deep averages, but this analysis is limited because there are only two deep April sampling runs. Nearly all of the shallow total phosphorus samples (85% of 39 samples) exceed the Cape Cod guidance concentration of 10 µg/L. Average total nitrogen concentrations also do not vary by season or depth and, similar to TP samples, 93% of the 40 shallow samples exceed the Cape Cod guidance concentration of 0.32 mg/L.

Recommendation/Summary

Coles Pond is impaired based on its high average chlorophyll (with blooms evident), total phosphorus, and total nitrogen concentrations well above Cape Cod guidance levels. The depressed summer DO levels also suggest an impaired ecosystem. Coles Pond is not listed in any capacity in the most recent MassDEP Integrated List¹³ even though its area exceeds the Great Pond (≥ 10 acres) threshold and, therefore, should be considered a public pond.

Although Coles Pond is impaired, given its characteristics and the general lack of significant use (*e.g.*, only 3 houses nearby), prioritizing Coles Pond for additional characterization to address data gaps (*e.g.*, sediment oxygen demand/nutrient release triggers), does not seem warranted. If Town wishes to move forward with a water quality management plan for Coles Pond or MassDEP requires such plan in order to satisfy the need to produce a TMDL under the Clean Water Act, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and triggers, 2) measurement of flow and nutrient loads in the hydroconnection between Coles Pond and the small pond along its southwest side, 3) complete a bathymetric map, 4) complete a freshwater mussel and aquatic plant survey to document the area covered (if any) and 5) identification of any stormwater discharges and measurement over at least three storms if any are identified. Once data is developed, it should be synthesized with the available pond water quality data and used to update the information in the 2009 Ponds Report (*e.g.*, the watershed delineation and nutrient budgets). Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

¹³ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Table III-3. Coles Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	1.43			1.60		1.31		<	
N	53			13		20			
Max	2.00			1.84		1.60			
Min	1.00			1.40		1.10			
Secchi Depth									
Average (m)	1.26			1.34		1.26			
N	54			14		20			
Max	1.65			1.65		1.50			
Min	0.69			0.80		0.82			
Temperature									
Average (°C)	18.60	18.81	18.17	14.21	13.74	22.53	22.67	>	>
N	95	64	31	13	11	23	14		
Max	27.70	27.70	26.90	17.30	17.20	27.70	26.90		
Min	4.03	4.03	7.10	10.60	10.50	16.50	16.60		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.80	8.85	8.69	9.98	9.91	7.46	7.67	<	<
N	93	62	31	13	11	22	14		
Max	15.29	15.29	12.79	11.47	11.32	9.00	9.05		
Min	5.84	5.87	5.84	8.65	8.63	5.87	5.84		
N < 5 mg/L DO	0	0	0	0	0	0	0		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	5.38	5.40	5.32	5.32	5.18	5.56	5.55		
N	56	46	10	10	3	21	6		
N < 6.5 pH	55	45	10	10	3	20	6		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	8.44	7.81	11.26	1.47	1.57	9.83	15.13	>	
N	38	31	7	7	2	19	5		
Max	46.09	46.09	20.91	2.99	2.70	46.09	45.91		
Min	0.45	0.57	0.45	0.63	0.45	0.62	0.75		
N > 1.7 µg/L	23	18	5	2	1	13	3		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	21.12	21.46	19.51	21.38	12.51	20.24	21.85		
N	47	39	8	9	2	20	6		
Max	61.60	61.60	1.51	44.00	19.04	48.94	46.46		
Min	2.24	2.24	0.36	2.24	5.97	4.00	5.27		
N > 10 µg/L	38	33	5	8	1	16	3		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.58	0.57	0.64	0.51	0.45	0.59	0.70		
N	48	40	8	9	2	22	6		
Max	1.51	1.08	1.51	0.75	0.47	1.08	1.51		
Min	0.15	0.15	0.36	0.38	0.44	0.15	0.36		
N > 0.32 mg/L	45	37	8	9	2	20	5		

III.D. Eagle Pond

Eagle Pond is a 7 acre pond located just to the south of the Mid-Cape Highway (Route 6) and just north of the Town landfill/transfer station. It is in an area that is sparsely developed except for a small, four house development to the northeast off Love Lane. There is a small pond to the southeast, which is sometimes connected to Eagle Pond during high groundwater conditions. There have been indications of past stormwater runoff from Route 6 toward the pond, although MassDOT committed to reworking the drainage outlet in 2013.¹⁴ Water quality in Eagle Pond was reviewed, along with a delineation of its watershed, in the 2009 Dennis Ponds Report. The Town began to move forward to address identified data gaps in 2012.¹⁵ The resulting 2012 CSP/SMASST technical effort focused on completing a survey of submerged vegetation and freshwater mussels, a bathymetric survey, and synthesizing WQAC volunteer bird counts.

Average depth at the water quality sampling station was 6.93 m (n=55) with no statistically significant difference between spring and summer average depths. There were 4 sampling runs when samplers missed the deep sampling location. Average Secchi/clarity readings were not significantly different in spring and summer (4.54 m vs. 3.90 m, respectively) with an average overall clarity of 60% of the water column.

Temperature profile data show that shallow and deep average temperatures are generally significantly different with colder deep waters, but the summer difference is not significant (average summer shallow = 24.2°C, while average summer deep = 23.2°C). Summer water column temperatures are significantly higher than spring temperatures (e.g., shallow April/May temperatures average 15.04°C, while August/September shallow temperatures average 24.28°C). The significant differences between shallow and deep temperatures during the spring and overall is somewhat surprising for such relatively shallow pond, but may be a function of the higher topography that nearly surrounds the pond (much like Cedar Pond), reducing wind driven vertical mixing during most of the year, but increased summer wind speeds cause more frequent mixing. Average dissolved oxygen concentrations have a somewhat similar pattern with average significant differences between shallow and deep (deep having lower concentrations), but spring and summer concentrations are not significantly different. Of the 328 collected DO readings, 6 (2%) are less than the MassDEP minimum (5 mg/L). Of these readings, 5 of the 6 occur during the summer in deep waters near the sediments.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Eagle Pond. Average chlorophyll concentrations are not significantly different in between shallow and deep or with season, but phaeophytin concentrations and, thus, total pigments are significantly higher during the summer than the spring. This relationship suggests that pond phytoplankton are going through fairly rapid bloom cycles in order to maintain the higher concentrations of phaeophytin, which is the first breakdown product of chlorophyll. Two-thirds (67%) of the surface chlorophyll readings are greater than the Cape Cod guidance limit (1.7 µg/L). TP and TN concentrations are not

¹⁴ December 14, 2012 letter from Mary-Joe Perry, District Highway Director, Massachusetts Department of Transportation to Suzanne Brock, Chair, Dennis Water Quality Advisory Committee.

¹⁵ CSP/SMASST Technical Memorandum. December 18, 2012. Eagle Pond and Cedar Pond Technical Support Project.

significantly different by depth or season with ~60% of summer shallow concentrations exceeding respective Cape Cod guidance limits.

Recommendation/Summary

Eagle Pond is slightly impaired with generally acceptable dissolved oxygen concentrations, but regular nutrient and chlorophyll concentrations above their respective guidance levels and occasional low clarity readings. There are no significant trends in these conditions, so water quality management largely depends on the goals for the use of the pond. Based on a review of available town information, the pond is not listed as part of the town recreational areas and does not have a public beach.¹⁶ Eagle Pond is not listed in any capacity in the most recent MassDEP Integrated List¹⁷, but this may be due to its size being less than the Great Pond 10 acre threshold. The 2009 Dennis Ponds Report recommended a low-level maintenance sampling program for Eagle Pond with April and August/September sampling that follows PALS protocols. This recommendation still holds unless there are additional pond use concerns.

If the Town decides to pursue more extensive management, there are few data gaps since the Town began to address previously identified data gaps in 2012.¹⁸ This prior CSP/SMASST technical support project completed a survey of submerged vegetation and freshwater mussels, conducted a bathymetric survey, and synthesized WQAC volunteer bird counts. This information found that Eagle Pond had a) a pond volume 3% smaller than previous bathymetry indicated, b) that freshwater mussels were not present in the pond, c) that the northern portion of the pond had the highest plant densities with nearly 50% of the shallower areas covered by aquatic plants, and d) showed less bird utilization of the pond than previously estimated. Additional data gaps to be addressed if the town decides to move forward with active management of Eagle Pond would be: 1) evaluation of the connection (to the extent it exists) between Eagle Pond and the small pond to the southeast, 2) collection and incubation of sediment cores to measure nutrient regeneration triggers and potential sinks, 3) installation of a dissolved oxygen probe with continuous readings to better understand the extent and duration of low oxygen conditions during the summer, and 4) measurement of stormwater inputs and associated nutrient loads (if any) from Route 6 and adjacent properties. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

¹⁶ Dennis Open Space and Recreation Plan. 2008. Park and Recreation Inventory.

<https://dennismaopenspaceandrecreationplan.wordpress.com/appendix-b-park-and-recreation-inventory/> (accessed 9/8/16).

¹⁷ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

¹⁸ CSP/SMASST Technical Memorandum. December 18, 2012. Eagle Pond and Cedar Pond Technical Support Project.

Table III-4. Eagle Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	6.93			7.03		6.90			
N	55			14		22			
Max	7.65			7.65		7.40			
Min	6.00			6.05		6.30			
Secchi Depth									
Average (m)	4.13			4.54		3.90			
N	56			14		21			
Max	6.50			6.50		5.80			
Min	1.56			2.40		1.56			
Temperature									
Average (°C)	19.75	20.76	18.76	15.04	12.52	24.28	23.16	>	>
N	338	54	47	14	13	20	19		
Max	27.70	27.70	27.50	19.41	16.18	27.70	27.50		
Min	9.20	12.00	9.30	12.00	9.30	20.50	18.99		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.80	8.98	7.84	10.48	9.88	7.86	7.25	<	<
N	328	55	44	14	13	21	17		
Max	12.80	12.80	11.98	12.08	11.98	9.23	8.90		
Min	3.51	6.39	3.90	9.74	6.96	6.39	3.99		
N < 5 mg/L DO	8	0	6	0	0	0	1		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	5.86	5.98	5.97	5.93	6.10	6.10	5.97		
N	107	39	34	11	10	19	17		
N < 6.5 pH	105	38	34	11	10	18	17		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	2.71	2.50	2.95	1.51	1.97	2.91	3.48		>
N	47	24	22	7	7	17	14		
Max	7.60	7.60	6.06	4.71	5.01	7.60	6.06		
Min	0.29	0.29	0.49	0.29	0.49	1.01	1.55		
N > 1.7 µg/L	33	16	16	2	3	14	12		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	13.98	13.91	12.05	14.28	12.58	11.27	10.72		
N	63	32	27	10	8	16	14		
Max	50.00	50.00	25.90	32.00	25.90	37.34	23.54		
Min	1.55	1.55	3.21	2.05	3.24	1.55	3.21		
N > 10 µg/L	40	21	16	7	5	8	7		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.33	0.33	0.34	0.39	0.41	0.33	0.33		
N	61	30	28	9	7	16	15		
Max	0.55	0.55	0.51	0.49	0.49	0.55	0.51		
Min	0.14	0.17	0.14	0.24	0.19	0.17	0.21		
N > 0.32 mg/L	31	17	14	7	7	9	6		

III.E. Flax Pond

Flax Pond is a 16 acre Great Pond located just to the north of Setucket Road and east of South Yarmouth Road. Only about a quarter of its shoreline is developed with residential dwellings; the 2009 Dennis Ponds Report noted that there were 39 properties within a 300 ft buffer of the pond. The rest of the shoreline is largely undeveloped, although the southeastern portion is connected to freshwater wetlands that were labeled as cranberry bogs on the most recent US Geological Survey topographic map. The bogs are no longer in production and are now part of the town's Flax Pond Conservation Area. Water quality in Flax Pond was reviewed in the 2009 Dennis Ponds Report, which included a delineation of its watershed and preparation of nutrient budgets.

Average depth of the water quality sampling station was 8.18 m (n=53) with no statistically significant difference between spring and summer average depths. There were 10 sampling runs when samplers missed the deep sampling location (*i.e.*, maximum depth shallower than two standard deviations from the mean/average depth). Average Secchi/clarity readings were 5.17 m and were not significantly different in spring and summer with an average overall clarity of 64% of the water column.

Temperature profile data show that shallow and deep average temperatures are generally significantly different throughout the year and during both spring and summer. Summer water column temperatures are significantly higher than spring temperatures (*e.g.*, shallow April/May temperatures average 14.61°C, while August/September shallow temperatures average 24.38°C). Review of summer profile data shows that the pond occasionally stratifies at approximately 6 m with much colder deeper waters and these occurrences are driving the differences between the averages. Average dissolved oxygen concentrations have a somewhat similar pattern with average differences between shallow and deep (deep having lower concentrations), but spring concentrations are not significantly different and summer concentrations are significantly different. Of the 393 collected DO readings, 19 (5%) are less than the MassDEP minimum (5 mg/L). Of these readings, 7 of the 19 occur in deep waters closest to the sediments and some of these are anoxic (<1 mg/L).

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Flax Pond. Average chlorophyll concentrations are not significantly different in between shallow and deep, but shallow summer concentrations are significantly higher than shallow spring concentrations; 44% of all chlorophyll concentrations exceed the Cape Cod Guidance Limit (1.7 µg/L) with most of these exceedances occurring during the summer. The average shallow summer phaeophytin concentration is also significantly higher than the corresponding spring average. TP and TN concentrations are not significantly different by depth or season with average shallow TP concentration of 10.3 µg/L overall, 10.2 µg/L in the spring, and 10.3 µg/L in the summer. However, ~50% of all TP concentrations exceed the Cape Cod Guidance Limit (10 µg/L TP), which suggests occasional exceptional sediment regeneration events, likely related to the occasional temperature stratification events.

Trend analysis generally shows weak relationships with regression coefficients typically much lower than 50% ($R^2 < 0.5$). However, notable results were that pH, deep total nitrogen and alkalinity concentrations have increased substantially over the 2001 to 2015 sampling period ($R^2 = 0.52$, $R^2 = 0.53$ and $R^2 = 0.54$, respectively). In addition, spring clarity, but not summer clarity, had an increasing trend since 2007 ($R^2 = 0.58$).

Recommendation/Summary

Flax Pond is slightly impaired with generally acceptable dissolved oxygen concentrations, but regular nutrient and chlorophyll concentrations above their respective guidance levels that seem to be associated with occasional thermal stratification. The trends in some of the factors suggest a complex set of ecological relationships. Given water quality conditions, water quality management largely depends on the goals for the use of the pond. Based on a review of available town information, the pond is part of a town conservation area with walking trails, but it is not listed for specific water quality uses, such as swimming or fishing. The 2009 Dennis Ponds Report recommended a low-level maintenance sampling program for Flax Pond with April and August/September sampling that follows PALS protocols and a review of data every 5 years. This recommendation still holds unless there are additional pond use concerns.

If the Town decides to pursue more extensive management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and triggers and potential sinks, 2) installation of continuous dissolved oxygen recorder during a summer to evaluate the development of stratification and the extent and duration of deep low oxygen events, 3) measurement of flow and nutrient loads in the hydroconnection between Flax Pond and the former cranberry bogs along the southern and southeast side, 4) complete a bathymetric map, 5) complete a freshwater mussel and aquatic plant survey to document the area of coverage and 6) identification of any stormwater discharges and measurement over at least three storms if any are identified (review of historic aerial maps suggest that there is a shoreline deposition delta near the end of Madison Road). Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan. Flax Pond is listed in the “No Uses Assessed” category of the most recent MassDEP Integrated List,¹⁹ which means at some point MassDEP should be prompted to review the available data and offer an official decision whether it is impaired and requires a TMDL or not.

¹⁹ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts’ Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Table III-5. Flax Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	8.25			8.43		8.08			
N	51			13		19			
Max	8.90			8.90		8.75			
Min	6.50			7.29		7.00			
Secchi Depth									
Average (m)	5.17			5.78		4.91			
N	53			13		20			
Max	8.60			8.60		7.55			
Min	2.55			3.26		2.55			
Temperature									
Average (°C)	19.63	20.87	16.29	14.61	11.97	24.38	20.66	>	>
N	395	53	33	13	9	20	10		
Max	28.00	28.00	25.23	16.96	15.20	28.00	24.00		
Min	9.00	11.90	9.00	11.90	9.00	20.50	14.20		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.42	8.83	7.02	10.47	10.18	7.84	4.72	<	<
N	392	52	32	12	9	20	10		
Max	12.38	12.38	12.02	12.38	12.02	9.09	8.94		
Min	0.07	5.92	0.07	9.67	7.41	5.92	0.07		
N < 5 mg/L DO	19	0	7	0	0	0	4		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	4.82	4.89	5.01	5.11	5.08	5.01	5.27		
N	116	36	25	11	8	16	10		
N < 6.5 pH	116	36	25	11	8	16	10		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	2.39	1.49	3.84	0.65	0.89	1.94	5.68	>	>
N	50	23	13	8	5	15	8		
Max	17.16	5.60	17.16	1.95	2.13	5.60	17.16		
Min	0.20	0.23	0.20	0.24	0.44	0.23	0.20		
N > 1.7 µg/L	21	8	6	1	1	7	5		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	10.49	9.31	12.26	8.28	11.53	9.44	12.99		
N	61	29	17	8	6	17	8		
Max	30.36	16.41	30.36	16.41	25.29	14.67	30.36		
Min	1.49	1.86	4.13	1.86	4.13	5.89	5.89		
N > 10 µg/L	29	12	9	2	3	8	3		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.19	0.17	0.23	0.19	0.24	0.19	0.28		
N	64	30	20	9	6	17	11		
Max	0.59	0.35	0.59	0.27	0.52	0.35	0.59		
Min	0.02	0.02	0.02	0.10	0.10	0.03	0.04		
N > 0.32 mg/L	8	3	5	0	1	3	0		

III.F. Fresh Pond

Fresh Pond is a 32 acre Great Pond located between Main Street and Route 134. Most of the shoreline is undeveloped and owned by the town (Fresh Pond Conservation Area, which also has a dog park) and the Dennis Conservation Trust (much of these areas are freshwater wetlands). There are some scattered houses along its west side and one on its east side. Fresh Pond was not reviewed in detail during the 2009 Dennis Ponds Report, but a watershed was delineated as part of the Bass River Massachusetts Estuaries Project (MEP) Report.²⁰ US Geological topographic map shows two streams along the southern shoreline with one connecting to the Bass River and the other appearing to drain from the southern wetland. Review of aerial photographs suggests extensive rooted plant stands especially along the western side of the pond.

Average depth at the water quality sampling station was 2.85 m (n=57) with a small but statistically significant difference between spring and summer average depths (2.99 m vs. 2.78 m, respectively). All deep sampling locations were within reasonable range. Average Secchi/clarity readings were very low, only 0.43 m, and were not significantly different in spring and summer with an average overall clarity of 15% of the water column. Clarity readings have no trend over the 2001 to 2015 measurement period.

Temperature profile data generally show that the water column had similar temperatures at shallow and deep depths most likely due to wind driven mixing of the shallow water column. Summer temperatures were significantly higher than spring temperatures at both shallow and deep depths. Summer shallow and deep temperatures average 23.17°C and 22.39°C, respectively, while corresponding spring temperatures were 14.82°C and 13.49°C, respectively. Dissolved oxygen concentrations follow somewhat of a similar pattern, but summer concentrations are significantly lower than spring concentrations and summer deep concentrations are significantly lower than summer surface concentrations. Of the 175 collected DO readings, 12 (7%) are less than the MassDEP minimum (5 mg/L). Of these readings, 6 of the 12 occur in deep waters closest to the sediments during the summer and are 33% of the summer deep dissolved oxygen readings. It should also be noted that average deep % DO saturation is significantly lower than surface concentrations in all readings and during both spring and summer; this suggests persistent sediment oxygen demand in excess of photosynthetic additions and oxygen ventilation from wind driven mixing of the water column with replenishment from the atmosphere. Average summer % DO saturation is also significantly lower than spring readings with surface readings averaging only 83% of saturation and deep readings 64% of saturation.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Fresh Pond. Average surface chlorophyll concentrations are generally significantly higher than deep concentrations with similar relationships during both seasons; 96% of all shallow chlorophyll concentrations exceed the Cape Cod Guidance Limit (1.7 µg/L) and are consistent with the low water clarity. The average shallow and deep phaeophytin concentrations are not significantly different during either season,

²⁰ Howes, B., S. Kelley, J.S. Ramsey, E. Eichner, R. Samimy, D. Schlezinger, P. Detjens. 2011. Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Bass River Embayment System, Towns of Yarmouth and Dennis, Massachusetts. Massachusetts Department of Environmental Protection. Boston, MA.

but summer shallow and deep concentrations are significantly higher than the corresponding spring averages suggesting a more rapid phytoplankton turnover during the summer. TP concentrations are not significantly different by depth (again due to mixing), but summer shallow and deep average concentrations are significantly higher than spring averages, which suggests summer sediment regeneration. Almost all (98%) of the TP concentrations exceed the Cape Cod Guidance Limit (10 µg/L TP). Chlorophyll, TP, TN, and pH readings have no significant trend over the 2001 to 2015 measurement period.

Recommendation/Summary

Fresh Pond is significantly impaired by nutrient enrichment with dissolved oxygen concentrations that generally exceed MassDEP minimums, but sediment oxygen demand that exceeds atmospheric replenishment throughout the year and which increases significantly during the summer. Almost all individual chlorophyll and total phosphorus concentrations exceed their respective Cape Cod Guidance Limits. Average Secchi/clarity readings are very low (~0.43 m) allowing light penetration for only 15% of the water column.

Fresh Pond is a Great Pond under state law because of its surface area, but is not included in the most recent MassDEP Integrated List.²¹ As a highly impaired Great Pond, it would be required to have a TMDL established, but a final determination would need to be completed by MassDEP. Given the close pairing of county 208 implementation with state TMDL implementation, it is reasonable to assume that at some point Fresh Pond and other Great Ponds with impaired conditions will receive more regulatory attention, but as of the writing of this report, it is uncertain when or in what form that attention will take.

If the Town decides to pursue water quality management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and triggers and potential sinks, 2) measurement of flow and water quality over a hydrologic year in the two streams connected to the pond, 3) installation of a continuous dissolved oxygen recorder during a summer to evaluate and quantify the duration and extent of potential low oxygen events missed by snapshot sampling, 4) complete a bathymetric map, 5) complete a freshwater mussel and aquatic plant survey to document the area of plant coverage and 6) identification of any stormwater discharges and measurement over at least three storms if any are identified (recent Phase II stormwater survey requirements may provide the necessary review). Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

²¹ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Table III-6. Fresh Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	2.85			2.99		2.78		<	
N	57			15		22			
Max	3.20			3.20		3.10			
Min	2.50			2.70		2.50			
Secchi Depth									
Average (m)	0.43			0.48		0.40			
N	53			13		21			
Max	0.76			0.73		0.70			
Min	0.23			0.30		0.24			
Temperature									
Average (°C)	19.27	20.02	18.77	14.82	13.49	23.17	22.39	>	>
N	177	54	46	14	12	22	19		
Max	27.81	27.81	26.03	18.70	17.40	27.81	26.03		
Min	9.40	9.40	9.40	11.29	9.85	18.40	18.40		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	7.77	8.18	7.01	9.65	9.39	7.12	5.60	<	<
N	175	55	45	14	12	22	18		
Max	11.82	11.42	11.38	10.71	10.60	9.77	7.52		
Min	2.23	5.17	2.23	8.58	8.10	5.62	2.30		
N < 5 mg/L DO	12	0	11	0	0	0	5		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	4.21	4.21	4.19	4.31	4.14	4.32	4.38		
N	78	40	24	11	6	20	11		
N < 6.5 pH	78	40	24	11	6	20	11		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	9.60	11.91	3.52	12.13	1.60	11.79	4.34		
N	48	24	10	8	3	16	7		
Max	28.55	28.55	14.26	28.55	3.31	22.63	14.26		
Min	0.004	0.01	0.004	0.01	0.004	3.89	0.03		
N > 1.7 µg/L	41	23	5	7	1	16	5		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	42.10	40.22	43.03	34.60	22.36	48.39	48.58	>	>
N	63	34	16	10	4	17	9		
Max	102.00	79.43	102.0	62.00	29.51	79.43	82.94		
Min	6.34	10.44	6.34	10.44	6.34	15.49	25.00		
N > 10 µg/L	62	34	15	10	3	17	9		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.81	0.80	0.82	0.75	0.61	0.88	0.90	>	>
N	66	35	17	10	4	18	10		
Max	1.31	1.18	1.31	1.03	0.67	1.18	1.31		
Min	0.42	0.42	0.52	0.55	0.52	0.50	0.57		
N > 0.32 mg/L	66	35	17	10	4	18	10		

III.G. Hiram Pond

Hiram Pond is a 1.0 acre pond (DE-235) located approximately 60 m from Cape Cod Bay and south of Hiram Pond Road. It is surrounded by 9 houses, all of which are setback from the pond more than 30 m. Hiram Pond was not reviewed in detail during the 2009 Dennis Ponds Report. Review of aerial photographs suggests a hydroconnection to an adjacent cranberry bog located east of Scarsdale Road; there is also another cranberry bog located 200 m south of the pond. Hiram Pond was sampled from 2001 to 2010; no sampling results are available since the PALS Snapshot of 2010.

Average depth at the water quality sampling station was 5.65 m (n=42) with no statistically significant difference between spring and summer average depths. This is quite deep for such a small pond. There were 12 sampling runs when samplers missed the deep sampling location (*i.e.*, generally with maximum sampling depths of 2.5 to 3 m). Average Secchi/clarity readings were very poor, only 0.47 m, with a large and significant difference between spring (0.67 m) and summer (0.38 m) averages. Average clarity was only 9% of the water column. Clarity readings have no significant trend over the 2001 to 2010 measurement period.

Temperature profile data generally show strong stratification that was generally present in spring profiles, strengthened during the summer (*i.e.*, greater difference between shallow and deep readings), and often persisted into fall, October or November. However, some October and November profiles show a mixed water column with relatively consistent temperatures from top to bottom. Given this, it should not be surprising that shallow and deep average temperatures were significantly different in the overall dataset, in spring, and in summer. It should also be noted that summer average temperatures (shallow 20.58°C and deep 10.35°C) were significantly higher than spring average temperatures (shallow 15.53°C and deep 8.53°C). These types of readings in a shallow pond are likely due to some combination of the small surface area to depth and the location of the pond in along the margin of the regional groundwater lens where deep, cold groundwater flow paths are being brought to the top of the water table.

Given the temperature stratification, the bottom waters are often isolated from upper waters and atmosphere that would replenish oxygen to balance uptake by sediments and bottom water respiration. As a result, bottom water DO levels are regularly lower than MassDEP minimum concentration (5 mg/L). These deep, often anoxic concentrations (<0.1 mg/L), cause the overall average DO from all available data to be less than 5 mg/L; of the 175 collected DO readings, 94 (54%) are less than the MassDEP minimum. These deep low DO readings are persistent year-round; spring and summer deep readings also average less than 5 mg/L (88% of all deep readings are less than 5 mg/L). Shallow and deep average concentrations are significantly different overall, during spring, and during summer; summer average concentrations are also significantly higher than spring average concentrations. Review of % DO saturation reinforce the DO review findings with average shallow readings (68%) showing that sediment oxygen demand is impacting the whole water column.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Hiram Pond. Average chlorophyll concentrations are generally not significantly different between shallow and deep, but are significantly different by season with a high average summer surface concentration of 20.1 µg/L

and all 19 summer surface and deep concentrations above the Cape Cod Guidance Limit (1.7 µg/L). Average shallow phaeophytin concentration and total pigment concentration are also significantly higher in the summer than in the spring due to the high rates of phytoplankton production. Review of total phosphorus averages show that the overall average surface TP concentration is 3X the Cape Cod Guidance Limit (10 µg/L TP) with a significant difference between surface and deep averages (deep TP average is 7X the guidance limit). Chlorophyll, TP, TN, and pH readings have no significant trend over the 2001 to 2010 measurement period.

Recommendation/Summary

Hiram Pond is significantly impaired with average dissolved oxygen concentrations less than the MassDEP minimum and chlorophyll and total phosphorus average concentrations that are well above Cape Cod Guidance Limits. It is clear that the high amounts of *in situ* production due to high nutrient levels coupled with stratification, results in sediment oxygen uptake greater than inputs of oxygen from photosynthesis and atmospheric replenishment. Almost all individual chlorophyll and total phosphorus concentrations exceed their respective Cape Cod Guidance Limits. Average Secchi/clarity readings are only 9% of the water column.

Hiram Pond is not listed in any capacity in the most recent MassDEP Integrated List²², but this likely due to its surface area (1.0 ac) being significantly less than the Great Pond 10 acre threshold. A review of town assessor parcel maps shows that most of the pond area is a privately-owned parcel (classified by the town assessor as an undevelopable residential parcel).²³ Private ownership of the pond suggests that public benefits would have to be discussed prior the commitment of public funds to restoration of this pond.

If the Town decides to pursue water quality management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and triggers and potential sinks, 2) measurement of flow and water quality over a hydrologic year if the hydroconnection to the bog system is found to be active, 3) complete a bathymetric map, 4) complete a freshwater mussel and aquatic plant survey to document the portion of the bottom area that is colonized by plants (if any) and 5) identification of any stormwater discharges and measurement over at least three storms of each major identified input (recent MS4 Phase II stormwater survey requirements may provide the necessary identification). Complementary water quality data should be collected at the time of addressing these data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

²² Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

²³ Town of Dennis GIS maps (<https://www.mapsonline.net/dennisma/index.html>; accessed 9/13/16).

Table III-7. Hiram Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	5.65			5.95		5.66			
N	42			8		15			
Max	6.50			6.40		6.25			
Min	3.80			5.10		3.80			
Secchi Depth									
Average (m)	0.47			0.67		0.38		<	
N	44			8		17			
Max	1.34			1.34		0.55			
Min	0.30			0.35		0.30			
Temperature									
Average (°C)	14.10	18.78	9.74	15.53	8.53	20.58	10.35	>	>
N	173	45	21	9	5	17	6		
Max	25.40	25.40	12.50	19.75	9.80	25.40	11.40		
Min	6.60	7.90	6.60	12.70	6.60	16.50	9.62		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	4.40	6.32	1.64	9.23	3.38	5.17	0.51	<	<
N	175	44	24	9	6	16	7		
Max	11.64	10.30	5.88	10.30	5.88	7.75	2.00		
Min	0.01	2.02	0.02	7.95	0.46	2.02	0.02		
N < 5 mg/L DO	94	13	21	0	3	6	7		
pH: MassDEP Lower Limit 6.5									
Average (stdnd)	5.29	5.26	5.61	5.30	5.17	5.52	5.96		>
N	82	31	19	6	4	14	9		
N < 6.5 pH	82	31	19	6	4	14	9		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	12.87	16.75	10.44	3.42	1.31	20.09	13.04	>	>
N	28	15	9	3	2	12	7		
Max	44.00	44.00	20.83	3.52	1.53	44.00	20.83		
Min	0.95	3.35	1.10	3.35	1.10	3.74	3.09		
N > 1.7 µg/L	24	15	7	3	0	12	7		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	42.48	29.96	72.32	30.78	45.40	34.73	83.70		
N	50	26	12	5	2	15	9		
Max	204.37	57.92	204.37	54.00	49.60	57.92	204.37		
Min	9.92	9.92	17.20	16.11	41.20	10.24	17.20		
N > 10 µg/L	49	25	12	5	2	15	9		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	1.04	0.92	1.30	0.75	0.97	1.01	1.39	>	>
N	49	25	12	5	2	14	9		
Max	2.10	1.27	2.10	0.85	1.02	1.18	2.10		
Min	0.40	0.40	0.70	0.61	0.91	0.71	0.70		
N > 0.32 mg/L	49	25	12	5	2	14	9		

III.H. North Simmons Pond

North Simmons Pond is a 5.6 acre pond (DE-325) located north of Setucket Road and east of Lady Slipper Drive in an area with South Simmons Pond and two smaller ponds to its east and west. The northern half of its shoreline is occupied by Dennis Water District land, while most of the parcels along its southern half are classified by the Town assessor as developable residential lots.²⁴ North Simmons Pond was not reviewed in detail during the 2009 Dennis Ponds Report. Review of aerial photographs and USGS quadrangles suggest it has a hydroconnection to the small pond located to the east and there is a relatively large freshwater wetland located west of the pond that appears to have once been a cranberry bog. North Simmons Pond was sampled from 2001 to 2015.

Average depth at the water quality sampling station was 5.81 m (n=56) with no statistically significant difference between spring and summer average depths. There were 13 sampling runs when samplers missed the deep sampling location (*i.e.*, generally deep sample shallower than 4.3 m). Average Secchi/clarity readings were 4.78 m with large and significant difference between spring (5.75 m) and summer (4.13 m) averages due to summer phytoplankton densities. Average clarity was 83% of the water column also with a significant seasonal difference. Clarity readings have no significant trend over the 2001 to 2015 measurement period.

Temperature profile data generally similar average readings at shallow and deep depths, although spring shallow readings are significantly higher than deep readings, likely showing more rapid surface warming; by summer there is no significant difference between shallow and deep readings. Average shallow and deep summer temperatures are, however, significantly higher than the corresponding spring readings (summer shallow and deep averages: 24.34°C and 23.61°C, while spring averages are: 15.17°C and 12.98°C, respectively). Shallow ponds typically have similar temperature readings at shallow and deep monitoring station because Cape Cod winds mix the water column.

Given the general lack of significant temperature stratification, it would be expected that average dissolved oxygen concentrations should be similar in shallow and deep waters, but overall and summer average DO readings show significantly lower deep concentrations indicating that vertical mixing is insufficient to balance sediment oxygen uptake. Spring average shallow and deep concentrations are not significantly different as uptake is lower in the cooler conditions. While the overall deep average concentrations are lower than surface concentrations (likely due to sediment oxygen demand), most of the deep concentrations are above the MassDEP regulatory minimum concentration (5 mg/L). There are 14 summer deep DO readings and 3 of these (21%) are less than 5 mg/L. As would also be expected because of higher temperatures, summer average DO concentration at both shallow and deep depths are less than spring averages: summer shallow and deep averages: 7.42 mg/L and 6.03 mg/L, while corresponding spring averages are: 10.52 mg/L and 10.54 mg/L. Although summer DO concentrations are generally above the MassDEP minimum, review of %DO saturation show notable reductions below atmospheric equilibrium in both shallow and deep summer averages. Spring %DO averages are generally at 100% (balance with atmospheric concentration), while summer averages are significantly lower (89% surface and 75% bottom) and significantly different from each other.

²⁴ Town of Dennis GIS maps (<https://www.mapsonline.net/dennisma/index.html>; accessed 9/13/16).

These readings show that sediment oxygen demand during the summer impacts the whole water column of North Simmons Pond.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in North Simmons Pond. Average chlorophyll and total phosphorus concentrations are generally not significantly different between shallow and deep or by season, although the average shallow chlorophyll concentration is significantly higher than the spring average (0.43 µg/L and 2.24 µg/L, respectively). The majority (63%) of the TP concentrations exceed the Cape Cod Guidance Limit (10 µg/L TP), while 45% of the chlorophyll concentrations exceed their respective Cape Cod Guidance Limit (1.7 µg/L). Most of the chlorophyll concentrations exceeding the Cape Cod limit are during the summer (only 2 occur in spring), with most of those occurring in shallow waters. TP exceedances also occur more frequently during the summer, but occur more frequently during the spring than the chlorophyll exceedances. Summer average surface chlorophyll and phaeophytin are significantly higher in the summer than the spring. All of the total nitrogen concentrations (n=65) are above the Cape Cod Guidance Limit (0.32 mg/L) with no significant difference between spring and summer concentrations. This finding is generally consistent with a constant input of nitrogen, which is likely from the surrounding aquifer system. Review of trends for the available water quality measures generally show no relationships ($R^2 < 0.5$) during the 2001 to 2015 measurement period.

Recommendation/Summary

North Simmons Pond is moderately impaired due to excessive phosphorus concentrations, Dissolved oxygen concentrations below the MassDEP minimum occur in 21% of summer deep readings and summer surface chlorophyll concentrations exceed the Cape Cod Guidance Limit in 53% of the 19 available readings. Average clarity declines 25% between spring and summer. This data review seems to indicate that the pond sediments are adding phosphorus and prompting phytoplankton growth during the summer, but this is not confirmed by the TP concentrations, which show relatively consistent concentrations with season and depth; some of these apparent difference may be due to the vertical mixing reducing spring to summer shifts in bottom waters and/or more transitory events that are not being measured by the snapshot monitoring approach. More refined, targeted data collection would be necessary to confirm this (*e.g.*, collection and incubation of sediment cores to evaluate DO triggers for phosphorus release). Given the general lack of development around the pond, it is unlikely that new significant additions of phosphorus will impact the pond in the near future.

North Simmons Pond is not listed in any capacity in the most recent MassDEP Integrated List²⁵, but this is most likely due to its surface area (5.6 ac) being significantly smaller than the Great Pond 10 acre threshold. A review of town assessor parcel maps shows that the pond itself is a separate polygon in the town-wide parcel map suggesting that it is publicly-owned land under the pond.²⁶ As such, water quality management would likely be the responsibility of the town,

²⁵ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

²⁶ Town of Dennis GIS maps (<https://www.mapsonline.net/dennisma/index.html>; accessed 9/13/16).

although more research would likely be necessary to confirm ownership and management responsibility.

If the Town decides to pursue water quality management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and potential sinks, as well as DO triggers for phosphorus release, 2) evaluation of any surface water connections to nearby ponds and wetlands and measurement of flow and water quality over a hydrologic year if any hydroconnections are identified, 3) complete a bathymetric map, and 4) complete a freshwater mussel and aquatic plant survey to document the bottom area colonized (if any). From a review of aerial photographs, it does not appear that any roads or impervious surface areas are near enough to the pond to generate stormwater discharges to the pond. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

Table III-8. N Simmons Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	5.81			5.88		5.68			
N	56			13		21			
Max	6.79			6.73		6.50			
Min	4.60			4.60		5.10			
Secchi Depth									
Average (m)	4.78			5.75		4.13		<	
N	55			12		22			
Max	6.70			6.60		5.90			
Min	2.60			4.60		2.90			
Temperature									
Average (°C)	20.57	21.21	19.93	15.17	12.98	24.34	23.61	>	>
N	284	57	39	13	9	23	15		
Max	28.30	28.30	27.20	18.77	15.20	28.30	26.46		
Min	9.20	12.20	9.20	12.20	9.20	20.40	20.30		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.53	8.64	7.69	10.52	10.54	7.42	6.03	<	<
N	273	56	36	13	9	22	14		
Max	12.13	12.13	11.96	12.13	11.96	9.10	8.18		
Min	1.61	5.81	1.61	9.76	9.62	5.81	1.61		
N < 5 mg/L DO	5	0	4	0	0	0	3		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	6.08	6.23	6.06	6.23	6.17	6.31	6.19		
N	100	39	23	10	8	21	11		
N < 6.5 pH	75	28	19	6	6	15	9		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	3.20	1.76	5.57	0.43	9.13	2.24	3.63	>	
N	51	26	17	7	6	19	11		
Max	34.89	4.87	34.89	0.65	34.89	4.87	8.57		
Min	0.12	0.12	0.50	0.23	0.50	0.12	1.10		
N > 1.7 µg/L	23	10	10	0	2	10	8		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	12.26	11.96	11.86	12.44	10.97	10.57	11.89		
N	65	35	18	10	6	20	11		
Max	34.21	31.00	16.78	31.00	15.24	19.82	16.36		
Min	2.48	2.48	5.58	2.48	5.58	5.22	9.29		
N > 10 µg/L	41	22	13	5	4	12	8		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.41	0.42	0.42	0.43	0.50	0.42	0.38		
N	65	34	19	9	7	20	11		
Max	0.75	0.61	0.75	0.55	0.75	0.58	0.44		
Min	0.23	0.28	0.31	0.35	0.34	0.33	0.35		
N > 0.32 mg/L	58	32	18	9	7	20	11		

III.I. Run Pond

Run Pond is an 8.1 acre pond (DE-348) located north of Setucket Road and south of Dennis Highlands Golf Course. It appears to be the part of the pond/wetland complex that is connected to Flax Pond. Based on a review of aerial photography, the area of the pond varies depending on groundwater level fluctuations. The area of the pond increases by approximately 1 acre during high groundwater conditions mostly due to flooding of shallow areas to the east and west of the main body of the pond. The pond is part of a Dennis Water District parcel that mostly surrounds the pond and occupies most of its northern shoreline.²⁷ Most of the parcels along its southern half are classified by the Town assessor as developable residential lots. Run Pond was not reviewed in detail during the 2009 Dennis Ponds Report. Review of aerial photographs and USGS quadrangles suggest that it has a hydroconnection to three small ponds/wetlands located to the east and also a connection to former cranberry bogs to the west that eventually connect to Flax Pond. Run Pond was sampled from 2001 to 2015.

Average depth at the water quality sampling station was 2.84 m (n=54) with a large statistically significant difference between spring (3.07 m) and summer (2.64 m) average depths. There were 18 sampling runs when samplers missed the deep sampling location (*i.e.*, maximum sampling depths generally 1.1 m to 1.6 m sampling depth). Average Secchi/clarity readings were 1.98 m with no significant difference between spring (2.37 m) and summer (1.90 m) averages and a minimum clarity of 0.65 m (2.1 ft). Average clarity was 74% of the water column, also without any significant seasonal difference. Clarity readings have no trend over the 2001 to 2015 measurement period.

Temperature profile data generally had significant difference between shallow and deep temperatures in the overall dataset and during the spring, but not during the summer. This finding is somewhat unexpected for such a shallow pond perhaps indicative of some seasonal difference, such as stronger winds at the pond during the summer creating more mixing of the water column, or may be due to the relatively limited number of deep data points during the summer period (n=5 for summer deep average compared to n=20 for the shallow summer average). Seasonal average shallow and deep summer temperatures are significantly higher than the corresponding spring readings (summer shallow and deep averages: 24.15°C and 21.30°C, while spring averages are: 15.82°C and 13.82°C, respectively). Shallow ponds typically have similar temperature readings at shallow and deep monitoring station because Cape Cod winds mix the water column, so the significant difference may be due to some sort of geologic control and/or changes in water table elevations.

The significant temperature differences at depth create conditions that would tend to favor lower deep oxygen concentrations due to some stratification and sediment oxygen demand. The overall shallow and deep DO averages are significantly different with no significant difference during the spring, but a significant difference during the summer. The summer deep average concentration (3.71 mg/L) is less than the MassDEP minimum. Both shallow and deep average summer concentrations (7.58 mg/L and 3.71 mg/L, respectively) are significantly less than the corresponding spring averages (9.51 mg/L and 8.80 mg/L, respectively). Among the 30 deep DO readings collected between 2001 and 2015, 11 (37%) are less than the MassDEP regulatory

²⁷ Town of Dennis GIS maps (<https://www.mapsonline.net/dennisma/index.html>; accessed 9/13/16).

minimum concentration (5 mg/L). All of the concentrations <5 mg/L occur at depths of 1.5 m or more. Review of %DO saturation levels show the impact of the sediments, especially during the summer when average deep %DO saturation is 42% of atmospheric equilibrium. This average is significantly less than summer shallow average (91%) and the overall shallow average (92%).

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Run Pond. Apparent sediment phosphorus regeneration during the summer causes a large increase in bottom water phosphorus concentration and deep N:P ratios to decrease and to be significantly less than the shallow ratio, but the ratios are not significantly different during the spring when bottom water DO is high or when all data is considered. Average chlorophyll and total phosphorus concentrations are not significantly different between shallow and deep or by season, although deep TP and both shallow and deep chlorophyll concentrations are higher during the summer, just not at the $p < 0.05$ level of significance. The majority (62%) of all the measured TP concentrations exceed the Cape Cod Guidance Limit (10 $\mu\text{g/L}$ TP), while 47% of the chlorophyll concentrations exceed their respective Cape Cod Guidance Limit (1.7 $\mu\text{g/L}$). Most of the chlorophyll concentrations exceeding the Cape Cod limit are during the summer (only 2 occur in spring), with most of those occurring in shallow waters. TP exceedances generally occur at the same frequency during both spring and summer, but all of the deep summer concentrations are above the guidance limit. Total nitrogen concentrations above the Cape Cod Guidance Limit (0.32 mg/L) occur more frequently during the summer, but there is no significant difference between shallow and deep or spring and summer average concentrations. These findings suggest that the low DO in bottom water during summer results in enhanced sediment nitrogen and phosphorus regeneration during the summer, but not at levels to create significantly different seasonal concentrations. Review of trends for the available water quality measures generally show no significant relationships ($R^2 < 0.5$) in the 2001 to 2015 measurement period, although a complex polynomial relationship can attain an R^2 between 0.5 and 0.6 for a decrease in alkalinity.

Recommendation/Summary

Run Pond is impaired due to: 1) year-round excessive phosphorus concentrations, 2) average deep summer DO depletion to concentrations below the MassDEP minimum, 3) average summer surface chlorophyll concentrations >2X the Cape Cod Guidance Limit and 4) clearly enhanced sediment regeneration of TP. This data review indicates that the pond sediments are adding phosphorus and prompting phytoplankton growth during the summer; a more refined, targeted data collection would be necessary to confirm this (e.g., collection and incubation of sediment cores to evaluate DO triggers for phosphorus release). Given the general lack of development around the pond, it is unlikely that new significant additions of phosphorus will impact the pond in the near future.

Run Pond (8.1 ac) is not listed in any capacity in the most recent MassDEP Integrated List²⁸, but this is likely due to its surface area being less than the Great Pond 10 acre threshold. As mentioned above, the pond is part of a parcel owned by the Dennis Water District.

²⁸ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Responsibility for the management of the pond would likely require discussions between the District and the Town.

If it is decided to pursue water quality management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and potential sinks, as well as DO triggers for release, 2) evaluation of the surface water connections to the east and west to and from the nearby ponds and wetlands, including measurement of flow and water quality over a hydrologic year, 3) complete a bathymetric map, and 4) complete a freshwater mussel and aquatic plant survey to document the bottom area covered (if any). From a review of aerial photographs, it does not appear that any roads are near enough to the pond to have stormwater discharges to the pond except perhaps the Water District access road that runs near its west side. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

Table III-9. Run Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	2.84			3.07		2.64		<	
N	54			14		20			
Max	3.64			3.64		3.20			
Min	2.10			2.60		2.10			
Secchi Depth									
Average (m)	1.98			2.37		1.90			
N	55			14		20			
Max	3.15			3.15		3.00			
Min	0.65			0.87		0.66			
Temperature									
Average (°C)	19.49	20.81	17.86	15.82	13.82	24.15	21.30	>	>
N	163	56	30	15	10	20	8		
Max	29.00	29.00	27.50	19.80	17.90	29.00	26.40		
Min	10.20	10.20	11.21	11.50	11.21	18.40	16.54		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	7.23	8.29	5.58	9.30	8.80	7.58	3.71	<	<
N	162	54	30	15	10	19	8		
Max	11.19	11.14	10.49	10.39	10.49	8.80	8.39		
Min	0.03	5.36	0.03	6.43	5.59	5.36	0.11		
N < 5 mg/L DO	21	0	11	0	0	0	5		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	5.01	5.10	4.85	5.23	5.07	5.24	5.34		
N	82	40	21	12	8	18	8		
N < 6.5 pH	82	40	21	12	8	18	8		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	6.48	3.62	8.67	1.55	1.01	4.65	15.06		
N	47	24	11	8	5	16	6		
Max	56.40	24.71	36.75	6.84	2.33	24.71	36.75		
Min	0.33	0.33	0.37	0.33	0.37	0.78	1.94		
N > 1.7 µg/L	22	10	7	1	1	9	6		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	15.49	13.83	17.69	14.02	14.93	13.80	21.17		
N	62	32	15	10	6	17	7		
Max	40.02	29.73	40.02	28.50	38.45	29.73	40.02		
Min	2.80	2.80	4.13	2.80	4.13	5.02	7.46		
N > 10 µg/L	42	18	12	6	4	9	6		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.46	0.44	0.51	0.39	0.37	0.49	0.64		
N	63	33	15	10	6	18	7		
Max	1.18	0.78	1.18	0.67	0.56	0.78	1.18		
Min	0.23	0.23	0.26	0.28	0.26	0.23	0.27		
N > 0.32 mg/L	43	22	11	5	3	15	6		

III.J. Scargo Lake

Scargo Lake is a 60 acre Great Pond (DE-236) located south of Route 6A and north of Scargo Hill Road. The pond has a town boat ramp off Route 6A and two town beaches (Princess Beach and Scargo Beach); most of the shoreline is developed with single-family residences except for the town parcels. It is the deepest and largest pond in the Town of Dennis and was reviewed in detail in the 2009 Dennis Ponds Report. The Town followed through on the recommendations in that report and began a two-part CSP/SMASST-led effort to develop a water quality management plan for the pond. In 2010, the town funded a targeted data collection project to address identified data gaps: 1) collection and incubation of sediment cores to measure nutrient fluxes from sediments at various depth, 2) a stormwater survey and collection of stormwater samples at identified direct discharge locations, 3) a year-long bird population survey coordinated through WQAC volunteers, and 4) an updated bathymetric map and freshwater mussel survey.²⁹ This collected information was combined with the previously collected PALS and other volunteer-collected data the following year to produce a water quality management plan.³⁰ This plan concluded that surface water conditions in Scargo Lake were acceptable for swimming and contact recreation and that total phosphorus and chlorophyll readings were elevated, “but not exceptionally high.”³¹ However, the authors concluded that impaired conditions existed deeper in the lake with regular anoxia, high sediment oxygen demand, and regenerated sediment phosphorus, and noted that clarity regularly declined throughout the summer. In order to address these impairments, it was recommended that the Town implement a hypolimnetic aeration system. This system would allow controlled injection of air into the deeper waters such that the cold water layer/habitat is maintained in the summer, oxygen levels are increased, and regeneration of phosphorus is reduced. Monitoring to measure the estimated improvements was also recommended. The Town prepared a 2013 Request for Qualifications to implement the plan. Scargo Lake has been sampled from 2001 to 2015.

Average depth at the water quality sampling station was 14.10 m (n=54) with no statistically significant difference between spring (14.39 m) and summer (14.15 m) average depths. There were 5 sampling runs when samplers missed the deep sampling location (*i.e.*, these runs had maximum sampling depths of 8 m to 10.7 m or much greater than 1 m above the average station depth). Average Secchi/clarity readings were 4.36 m with no significant difference between spring (4.77 m) and summer (4.25 m) averages and a minimum clarity of 2.25 m (7.4 ft). Average clarity was 30% of the water column, also without any significant seasonal difference. Clarity readings have no significant trend over the 2001 to 2015 measurement period.

As a deep pond, Scargo Lake thermally stratifies beginning in April with upper waters warming faster than they can be mixed into the rest of the water column, eventually leading to mid-summer temperature differences of at least 10°C between surface and deep waters that usually persist into November. As such, average temperatures were significantly different between shallow and both 9 m and deep temperatures in the overall dataset and during both spring and summer. Average temperatures in shallow waters and 3 m waters did not have significant

²⁹ Coastal Systems Program Technical Memorandum: Scargo Lake Technical Support Project. February, 2012. To: Virginia Esau, Chair, Water Quality Advisory Committee and Karen Johnson, Director of Natural Resources, Town of Dennis

³⁰ Eichner, E., B. Howes, and D. Schlezinger. 2012. Scargo Lake Water Quality Management Report. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 65 pp.

³¹ Executive Summary, p. EX1. 2012 Scargo Lake Water Quality Management Report.

differences since these waters continue to mix throughout the summer. In addition, shallow and deep average summer temperatures, as well as those at 3 m and 9 m were significantly higher than those in the spring (summer shallow, 3 m, 9 m, and deep averages: 23.59°C, 23.56°C, 17.54°C, and 11.34°C; spring shallow, 3 m, 9 m, and deep averages: 13.53°C, 13.02°C, 9.54°C, and 8.27°C). The colder deep waters in Scargo Lake could sustain a cold water fishery, as defined in MassDEP regulations, except for its prolonged hypoxia.

The significant temperature differences at depth create conditions that would tend to favor lower deep oxygen concentrations due to sediment oxygen demand. In April/May, when the water column has deeper mixing, average DO concentrations are not significantly different among the shallow, 3 m, and 9 m depths. When the summer warming creates a thinner upper layer, the DO averages at the shallow and 3 m depths are still not significantly different, but the 9 m depth average is significantly different from both shallower depths. Summer average DO at the shallow depth, 3 m, 9 m and deep depth are all significantly lower than the corresponding spring averages. The MassDEP minimum DO concentration is higher in cold water fisheries (6 mg/L DO) since cold water fish, such as trout, are more sensitive to low DO concentrations. Average summer concentrations at 9 m and the deep station in Scargo Lake are significantly lower than the MassDEP minimum concentration: 2.82 mg/L and 0.39 mg/L, respectively. Overall, 114 of the 634 DO readings (18%) for Scargo Lake are less than the MassDEP minimum with 95% of the summer readings below the minimum at 9 m and deep stations.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in Scargo Lake. Ratios are not significantly different between spring, summer or when all data is considered. The enhanced phosphorus release from the sediments during the summer low DO period can be clearly seen in the very high bottom water TP levels in summer compared to winter. The majority of individual chlorophyll (73%) and total phosphorus (77%) concentrations are above their respective Cape Cod Guidance Limits (1.7 µg/L and 10 µg /L, respectively). Average chlorophyll concentrations are not significantly different with depth or season except at 9 m; spring and summer 9 m chlorophyll averages are significantly higher than corresponding shallow and 3 m averages and 9 m summer average is significantly higher than 9 m spring average. This finding would be consistent with phytoplankton adjusting their buoyancy to utilize the high phosphorus concentrations in the deeper waters. In other deep ponds, this phytoplankton behavior often creates a zone of supersaturated DO near the cold water layer, a pattern that is sometimes measured in Scargo Lake. Total phosphorus concentrations generally show the impact of sediment TP regeneration, especially during the summer. Spring average concentrations are not significantly different with depth and summer averages are not significantly different except for the deep station, which is much higher than all the shallower averages. However, spring and summer average TP concentrations are not significantly different at any of the corresponding depths (spring deep average was 23.4 µg/L, while summer deep average was 39.48 µg/L; these are significantly different at a $p=0.08$ level of significance). Total nitrogen concentrations also show the impact of sediment regeneration during the summer; since low oxygen conditions generally must persist for long periods for nitrogen regeneration to be enhanced, these results show the severe extent and persistence of the anoxic conditions in Scargo Lake. Deep TN average concentrations are significantly higher than shallower averages during both the spring and the summer and the deep summer TN average concentration is significantly higher than the

deep spring average. Overall, 84% of the TN concentrations are above the Cape Cod Guidance Level (0.32 mg/L). Review available water quality measures over time generally show increasing, but no significant, trends ($R^2 < 0.5$) in the 2001 to 2015 measurement period.

Recommendation/Summary

As noted in the 2013 Management Plan, Scargo Lake is impaired due to: 1) persistent summer anoxia with average deep and 9 m summer DO concentrations below the MassDEP regulatory minimum, 2) clear enhancement of sediment regeneration of TP during low DO periods yielding a significant seasonal impact near the thermocline (layer of significant temperature change), and 3) average summer surface chlorophyll concentrations >2X the Cape Cod Guidance Limit. This data review indicates that the pond sediments are adding excess phosphorus (and nitrogen) and prompting phytoplankton growth during the summer. Sediment cores collected and incubated as part of the data gap assessment completed prior to the Management Plan preparation confirmed the role of low DO sediment nutrient release and directly measured the sediment TP release. Given the general lack of development around the pond, it is unlikely that new significant additions of phosphorus will impact the pond in the near future.

Scargo Lake is listed in the “No Uses Assessed” category of the most recent MassDEP Integrated List,³² which means at some point MassDEP should be prompted to review the available data and offer an official decision whether it is impaired and requires a TMDL or not. Given the lake’s area, it is clear that it is a Great Pond under Massachusetts law and, thus, is a publicly-owned resource. As an impaired Great Pond, it would be required to have a TMDL established, but a final determination would need to be completed by MassDEP. Given the close pairing of county 208 implementation with state TMDL implementation, it is reasonable to assume that at some point Scargo Lake and other Great Ponds with impaired conditions will receive more regulatory attention, but as of the writing of this report, it is uncertain when or in what form that attention will take.

The process that the Town went through to develop the 2013 Water Quality Management Plan, including collection of information to address the notable data gaps at the time, has provided a recommended course for water quality management of Scargo Lake. The data review completed for this project has generally confirmed the data review in the Management Plan.

³² Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts’ Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Table III-10. Scargo Lake Water Quality Summary. Statistically significant differences between shallow (S) and other depths means/averages are shaded blue (other comparisons are not included). Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.																	
	All data	All data				Apr/May				Aug/Sept				Seasonal difference			
		S	D	S	D	S	D	S	D	S	D	S	D				
Total Depth																	
Average (m)	14.1					3.1				2.6					<		
N	54					14				20							
Max	16.0					3.6				3.2							
Min	12.0					2.6				2.1							
Secchi Depth																	
Average (m)	4.4					2.4				1.9							
N	54					14				20							
Max	7.8					3.2				3.0							
Min	2.2					0.9				0.7							
Temperature		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (°C)	16.3	19.3	19.1	13.6	10.1	13.5	13.0	9.5	8.3	23.6	23.6	17.5	11.3	>	>	>	>
N	647	56	36	32	35	14	11	11	13	20	14	11	10				
Max	27.9	27.9	27.0	22.3	15.3	16.2	15.7	12.3	11.1	26.9	27.0	22.3	13.1				
Min	6.4	9.6	9.9	7.7	6.4	10.3	10.5	7.7	6.4	20.9	20.7	14.0	9.8				
Dissolved Oxygen: MassDEP Min 6 mg/L		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (mg/L)	7.8	9.3	9.1	6.7	3.8	11.1	10.9	10.8	6.2	8.2	7.9	2.8	0.4	<	<	<	<
N	634	54	35	32	38	14	10	11	13	19	14	11	10				
Max	14.1	13.4	11.6	13.1	10.1	13.4	11.6	13.1	9.1	9.1	8.6	7.8	2				
Min	0.0	6.1	6.9	0.0	0.0	9.8	9.8	8.4	0.7	7.0	6.9	0.0	0.0				
N > 6.0 mg/L	114	0	0	11	26	0	0	0	6	0	0	10	10				
pH: MassDEP Min 6.5		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (stdn)	6.6	6.6	6.8	6.6	6.4	6.5	6.8	6.6	6.3	6.9	6.8	6.5	6.4				
N	223	40	24	24	35	11	8	8	9	18	14	14	16				
N < 6.5 pH	87	15	5	9	22	5	2	3	5	3	3	6	12				

Table III-10. Scargo Lake Water Quality Summary (continued). In general, deep summer TP and TN concentrations are significantly higher than shallower averages. Chlorophyll average concentrations at 9 m are significantly higher than averages at other depth during the summer and in the overall dataset. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data				Apr/May				Aug/Sept				Seasonal difference			
		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (µg/L)	4.3	3.4	3.1	6.5	4.5	2.7	2.5	4.0	4.3	3.5	3.2	8.1	4.9				>
N	131	25	23	24	21	7	7	7	6	16	14	15	13				
Max	14.1	8.3	7.1	14.3	26.9	5.6	5.1	11.2	9.2	8.3	7.1	14.3	26.9				
Min	0.0	0.6	0.6	0.6	0.0	0.6	0.6	1.1	0.5	1.5	1.2	3.5	0.0				
N > 1.7 µg/L	95	20	18	22	9	4	5	6	4	14	11	15	4				
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (µg/L)	17.6	12.2	11.9	13.7	29.8	14.4	13.7	14.7	23.4	10.6	10.7	13.6	39.5				
N	146	32	23	24	31	9	8	8	8	16	13	14	15				
Max	79.3	24.1	19.6	25.0	79.3	24.1	19.6	25	63.6	21.0	18.7	24.7	79.3				
Min	1.6	1.6	1.6	1.6	8.0	5.0	4.3	2.6	9.5	1.6	1.6	1.6	10.2				
N > 10 µg/L	113	22	16	17	29	7	6	6	7	10	11	10	15				
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L		S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D	S	3 m	9 m	D
Average (µg/L)	0.53	0.35	0.37	0.39	0.87	0.35	0.40	0.40	0.48	0.35	0.35	0.36	1.18				>
N	151	33	24	24	32	8	8	7	8	18	15	15	16				
Max	2.10	0.53	0.60	0.59	2.10	0.42	0.60	0.45	0.79	0.46	0.48	0.52	2.10				
Min	0.17	0.21	0.17	0.24	0.19	0.23	0.27	0.32	0.31	0.21	0.17	0.24	0.33				
N > 0.32 mg/L	127	22	19	20	30	5	6	7	7	12	12	11	16				

III.K. White Pond

White Pond is a 12.1 acre Great Pond (HA-414) located directly north of Route 6 and west of Lynch Lane. The town line between Harwich and Dennis runs north to south through the pond with roughly half of the pond surface in each town. The pond shape appears to be a classical kettlehole pond with no surface water inflows or outflows. No bathymetric map is available and it was not selected for more detailed analysis in the 2009 Dennis Ponds Report. Most of the parcels along its shoreline are developed with residential land uses generally on lots of 1 acre or larger. The Town of Harwich volunteers have also sampled White Pond, but this data is not included in this review. White Pond was sampled from 2001 to 2015.

Average depth at the water quality sampling station was 7.14 m (n=54) with no statistically significant difference between spring (7.47 m) and summer (6.83 m) average depths. There were 8 sampling runs when samplers missed the deep sampling location (*i.e.*, generally deep sampling depths of 3.0 m to 4.5 m or much shallower than 1 m over the average station depth). Average Secchi/clarity readings were 5.28 m with the average summer reading (4.80 m) significantly less than the average spring reading (6.01 m); minimum clarity of 3.10 m (10.1 ft). Average clarity was 77% of the water column with no significant seasonal difference. Clarity readings have no significant trend over the 2001 to 2015 measurement period.

Temperature profile data generally had no significant difference between shallow and deep temperatures in the overall dataset or during the summer, but the average spring readings were significantly different. This finding is generally consistent with the relatively circular shape of the pond and its depth; ponds of this shape and size on Cape Cod generally have similar temperatures throughout the water column due to regular mixing by area winds. Average shallow and deep summer temperatures are significantly higher than the corresponding spring readings (summer shallow and deep averages: 24.05°C and 23.22°C, while spring averages are: 14.69°C and 12.90°C, respectively).

The relatively consistent temperatures throughout the water column tend to create conditions that favor a similar pattern for dissolved oxygen concentrations. Average shallow and deep DO concentrations are not significantly different and seasonal shallow and deep averages are also not significantly different. Summer averages, however, are significantly lower than the corresponding spring averages reflecting the higher oxygen uptake rates and lower DO capacity: summer shallow and deep averages: 7.74 mg/L and 6.26 mg/L, while corresponding spring averages are: 10.90 mg/L and 10.37 mg/L. Overall, 7 of the 337 White Pond DO readings (2%) are less than the MassDEP minimum with 5 of the <5 mg/L readings occurring at deep stations. Review of %DO saturation levels generally are consistent with the DO readings; only 14 of the 337 readings (4%) exceed 120% of atmospheric saturation. Average surface %DO in the spring and summer are significantly different, but both are near 100%: spring, 108%; summer, 92%. Deep summer saturation averaged 73%, with an average concentration of 6.3 mg/L.

Nitrogen to phosphorus ratios show that the pond is phosphorus sensitive, so management of phosphorus is the key for managing water quality in White Pond. Apparent sediment phosphorus regeneration during the summer causes deep N:P ratios to decrease and to be significantly lower than the shallow ratio; this relationship also exists in the overall dataset, but not in the spring comparison. Spring and summer ratios are not significantly different. These

relationships are the same as those for average total phosphorus concentrations; shallow average concentrations during all seasons and overall are less than the Cape Cod Guidance Limit (10 µg/L TP). Overall, spring, and summer deep average TP concentrations are all higher than surface averages with significantly higher concentrations overall and during the summer. It is notable that deep spring average TP is higher than the corresponding summer average (25.7 µg/L and 12.2 µg/L, respectively, but not significantly different because of variability); all data fits within statistical ranges, but this is unusual and would require more analysis to clarify. As might be expected because of these conditions, the average shallow spring chlorophyll concentration (2.1 µg/L) is slightly higher than summer concentration (1.8 µg/L). Summer total pigment concentration are higher than corresponding spring concentrations with most of the difference due to an increase in phaeophytin (summer surface average is significantly higher than the spring average), which indicates a larger summer phytoplankton community with a rapid turnover. Overall, 60% of the chlorophyll concentrations exceed the Cape Cod Guidance Limit (1.7 µg/L) with a relatively even distribution between shallow and deep readings, but mostly occurring during the summer. Total nitrogen concentrations are not significantly different either with depth or season, but spring average concentrations are higher than summer averages. Overall, 31% of the TN concentrations exceed the Cape Cod Guidance Limit (0.32 mg/L). Deep TN concentrations show a relatively significant increasing trend with a $R^2=0.52$, which suggests that the pond has retained and is recycling more nitrogen during the 2001 to 2015 measurement period. None of the other trend analysis reviews for the available water quality measures show substantial trends ($R^2 < 0.5$) in the 2001 to 2015 measurement period, although there is an increasing trend in alkalinity since 2007 in both shallow ($R^2=0.71$) and deep ($R^2=0.66$) readings.

Recommendation/Summary

White Pond is generally not impaired, but has conditions that warrant continued monitoring. Chlorophyll readings are generally just above the Cape Cod Guidance Limit, which suggest that the system is generally functioning in an acceptable fashion. Clarity, DO, and TP all seem to generally confirm this assessment. However, anoxic deep dissolved oxygen concentrations have been measured in a third of the August readings and deep August TP concentrations show the influence of periodic hypoxia, and have an upward trend ($R^2=0.56$).³³ In addition, the overall increasing trend in the deep TN concentrations seems suggest that more nutrients are being captured by the pond and this may eventually alter some of the other measures bringing the pond into an impaired category. With this in mind, it seems to be prudent to continue to monitor the water quality and track the measures that would indicate that more active management should occur.

White Pond is a Great Pond under state law because of its surface area (12.1 acres), but is not included in any capacity in the most recent MassDEP Integrated List.³⁴ If it is not judged to be impaired by MassDEP, it would not be required to have a TMDL established, although MassDEP has established a number of “Pollution Prevention” nutrient thresholds to ensure that unimpaired water bodies continue to be unimpaired. Final determination of its water quality

³³ September readings do not have this trend, but September deep readings all occurred in prior to 2009, while all August readings all occurred after 2005.

³⁴ Massachusetts Department of Environmental Protection. December, 2015. Massachusetts Year 2014 Integrated List of Waters, Final Listing of the Condition of Massachusetts’ Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act. MassDEP, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

status would need to be completed by MassDEP and the Town could petition MassDEP for a formal response during the public comment period for the development of the next Integrated List. Given the close pairing of county 208 implementation with state TMDL implementation, it may be to the Town's advantage to have a formal response in order to assist with prioritization of water quality planning activities.

If the Town decides to pursue more active water quality management, the following data gaps should be addressed: 1) collection and incubation of sediment cores to measure nutrient release rates and potential sinks, as well as DO triggers for release, 2) installation of two continuous data loggers to measure dissolved oxygen at shallow and deep depths from April through October, 3) complete a bathymetric map, and 4) complete a freshwater mussel and aquatic plant survey to document the bottom area covered (if any). From a review of aerial photographs, it does not appear that any roads are near enough to the pond to generate stormwater discharges to the pond, but this could be confirmed through the recent MS4 inventory review. Complementary water quality data should be collected at the time of addressing these specified data gaps in order to provide contemporary data. Combining the information from these data gaps with available water quality data should be sufficient to develop a management plan.

Table III-11. White Pond Water Quality Summary. Statistically significant differences in shallow and deep means/averages are shaded blue. Significant differences between seasonal means (Apr/May vs. Aug/Sept) are indicated in the last two columns. Statistics are based on database with outliers removed.

	All data	All data		Apr/May		Aug/Sept		Seasonal difference	
		shallow	deep	shallow	deep	shallow	deep	shallow	deep
Total Depth									
Average (m)	7.14			7.47		6.83			
N	54			14		21			
Max	9.10			9.10		8.15			
Min	4.50			5.22		4.50			
Secchi Depth									
Average (m)	5.28			6.01		4.80		<	
N	54			14		22			
Max	7.35			7.00		6.80			
Min	3.10			4.95		3.10			
Temperature									
Average (°C)	19.82	20.63	19.02	14.69	12.90	24.05	23.22	>	>
N	348	55	40	14	11	22	15		
Max	28.00	28.00	27.30	18.09	16.10	27.96	27.10		
Min	10.10	10.36	10.10	12.40	10.10	19.70	19.60		
Dissolved Oxygen: MassDEP Limit 5 mg/L									
Average (mg/L)	8.80	8.88	8.07	10.90	10.37	7.74	6.26	<	<
N	337	53	37	12	8	22	15		
Max	13.11	11.84	13.01	11.84	13.01	9.81	12.23		
Min	0.03	6.60	0.03	10.04	2.80	6.60	0.03		
N < 5 mg/L DO	7	0	5	0	1	0	3		
pH: MassDEP Lower Limit 6.5									
Average (stnd)	5.95	6.18	6.00	6.30	6.08	6.17	6.05		
N	133	38	26	11	9	22	12		
N < 6.5 pH	120	33	25	8	8	20	12		
Chlorophyll: Cape Cod Guidance Limit 1.7 µg/L									
Average (µg/L)	2.51	1.92	2.96	2.13	2.09	1.82	3.48		
N	52	24	16	8	6	16	10		
Max	10.74	5.88	10.74	5.88	4.73	3.86	10.74		
Min	0.37	0.37	0.66	0.37	0.66	0.52	1.51		
N > 1.7 µg/L	31	10	12	3	4	7	8		
Total Phosphorus: Cape Cod Guidance Limit 10 µg/L									
Average (µg/L)	11.86	9.05	17.48	9.46	25.69	7.92	12.19		
N	70	32	22	8	8	19	12		
Max	75.01	16.02	75.01	14.18	75.01	12.27	21.44		
Min	1.55	1.55	3.17	5.08	3.17	1.55	7.57		
N > 10 µg/L	34	14	14	4	5	5	7		
Total Nitrogen: Cape Cod Guidance Limit 0.32 mg/L									
Average (mg/L)	0.28	0.27	0.29	0.32	0.36	0.27	0.27		
N	71	34	21	9	8	20	12		
Max	0.65	0.43	0.65	0.39	0.65	0.43	0.42		
Min	0.09	0.12	0.13	0.24	0.13	0.15	0.14		
N > 0.32 mg/L	22	12	7	5	5	6	2		

IV. Monitoring Adjustments and Database Preparation Findings

Organization of the Town of Dennis pond water quality data from 2001 to 2015 revealed some findings that should be incorporated into current and future monitoring and data review:

a. Data should be reviewed more frequently

It is clear from reviewing the monitoring data that an effort should be made to compare field data to past data during the same sampling period and review data every 1 to 3 years. If field data is exceptionally uncharacteristic of past data for a given month or season, field data should be collected again at the earliest convenience. Recorded data with transposed DO and temperature readings could also be assessed/corrected at this stage. Laboratory data should also be reviewed when it becomes available. Obviously, this data cannot be resampled, but it will provide an opportunity to clarify any questionable data with the lab.

b. Changes in laboratories or data equipment should be carefully considered

Data in the cumulative Dennis Ponds water quality database is primarily from Cape Cod PALS Snapshots and Town Spring sampling. All of these laboratory analyses (*e.g.*, total phosphorus, total nitrogen, etc.) were generated through the SMAST Coastal Systems Analytical Facility. This laboratory has provided analyses for all 15 years of PALS Snapshots, previous Dennis Ponds targeted data collection (*e.g.*, Scargo Lake Management Plan), and all of the Massachusetts Estuaries Project (MEP) water quality sampling. The SMAST lab maintains regular internal testing procedures, had its lab and quality control methods and procedures approved by both MassDEP and USEPA, and is regularly reviewed through federal agencies via blind standards testing. The cumulative database includes a couple of summers of data (2003-2004) provided by the Cape Cod National Seashore lab. Inter-laboratory comparisons were not completed, but the statistical analyses do not identify a higher percentage of Seashore lab data as outliers. However, within the cumulative dataset are some problematic pH data that was generally collected during 2005. It is not clear how this data was generated (using a pH meter, Hach kit, lab data?), but it was not generated through the SMAST lab and most of this data resulted in statistical outliers. Most of the outliers are readings highly unlikely to be accurate (*e.g.*, pHs between 2 and 3). Statistical analysis removed these data from the reported averages. Collection of data without qualified and appropriate review of methods or laboratory techniques has the potential to create this type of unusable data. For example, largely as a result of the 2005 pH monitoring, Scargo Lake had 39 readings that were classified as outliers. This type of data and the effort to generate it, however well intentioned, was generally not worth the time to collect the samples and resulted in data that was not useful. Since the pond data will eventually be used to decide how management of these ponds should be implemented, care should be taken to ensure that the data is generated in appropriate settings with appropriate equipment by appropriate personnel.

c. Deep station sampling locations should be standardized

The PALS approach has relied on volunteers identifying the deepest location from either local knowledge or review of available bathymetric maps. It was anticipated that this approach would have some variability, including variability associated with groundwater level fluctuations. Review of the dataset, however, found that a notable portion of the

ponds had deep samples were not collected at a depth that would be representative of the deep water conditions in the pond. It is suggested that a hand held GPS be used to identify the deepest locations in all the ponds (perhaps in tandem with development of bathymetric maps for those ponds that do not have this information) and that the GPS coordinates be used to guide samplers to sampling locations in the future. Maximum depth information in this report can be used to guide selection of long-term sampling locations.

- d. Selection of management standards should be based on Cape Cod-specific data
Review of the available data shows that some of the MassDEP state-wide regulatory standards are not appropriate for assessing Cape Cod ponds and lakes. For example, the state surface water regulations state that pond pH “Shall be in the range of 6.5 through 8.3 standard units but not more than 0.5 units outside of the natural background range” (314 CMR 4.05(3)(a)3). All of the average pH readings for the Dennis ponds are lower than 6.5 and over 95% of the individual readings are less than 6.5. The MassDEP regulation allows for a “natural background range”, but some of the Dennis ponds have higher averages than others raising the issue about whether background should be based on pond-specific characteristics.

The Massachusetts Estuaries Project, which was funded jointly by the towns of southeastern Massachusetts, MassDEP, UMass Dartmouth, and other governmental and advocacy organizations, developed characterizations of each individual estuary and used that information to develop assessments of whether the ecosystems and water quality in each estuary was impaired and, if it was impaired, what an appropriate nutrient/nitrogen threshold should be for effective water quality management. This finding raises the issue whether there should be similar assessment completed for the ponds of Cape Cod or some portion of the pond population (*e.g.*, only Great Ponds).

At very least, review of the data and the available state-standards raises the issue of whether there should be Cape Cod-specific pond water quality goals/standards. USEPA has recommended an approach to set water quality standards for ponds and lakes in similar hydrogeologic and climate settings. This general approach was utilized during the review of the 2001 PALS Snapshot data and the development of the Cape Cod-specific Guidance Limits that are detailed in the Cape Cod Pond and Lake Atlas and utilized in this review.

V. Recommendations

Based on the review of the Town of Dennis pond water quality data, project staff has a number of recommendations:

1. Dennis Pond Water Quality Sampling QAPP should be prepared

The PALS Snapshot program has generally had very limited funding throughout its history and has relied extensively on the volunteer time of citizens and professional staff at the involved agencies and programs. The data sampling approach was developed by professional staff and training of volunteers was implemented on a regular basis. However, most of these procedures have not been documented specifically for the Town of Dennis. It is recommended that the Town prepare a Quality Assurance Project Plan (QAPP) for Dennis Pond water quality sampling to ensure that all procedures are documented. Preparation of a QAPP will also ensure that all data will be accepted by state and county regulators. A QAPP could include location of sampling points, frequency of sampling, frequency and procedures for data review, and use of data.

2. Management Objectives for all ponds should be considered

The review completed in this project identified ponds that had a number of management settings within current law, regulations, and ownership. In addition, the data review specifically indicated that some of the ponds are impaired, some are not impaired, and some are in transition from unimpaired to impaired (*e.g.*, slightly impaired). Most of the ponds have been managed in a way that is sometimes termed “inadvertent management” where development within the watershed, along the pond shore, or in the pond has water quality or ecosystem impacts, but these impacts have not been considered in an extensive or cumulative way relative to pond health.

It is recommended that the Town consider developing “active” management objectives for each pond. These objectives may range from actively pursuing water quality management techniques within the pond or watershed to simply monitoring the pond annually. Development of such objectives could be reviewed on a regular basis (1 to 3 years) along with available monitoring data to regularly evaluate changes and reassess objectives. It would also be an opportunity to include tangentially-associated objectives for individual ponds, such as boating goals, dock lengths, and fishery or plant habitats. Development of such a town-wide plan would allow the town to prioritize any targeted data collection and provide a strategy for all the ponds in town, including those that do not have regular monitoring data.

3. Try to integrate/coordinate management objectives across all resources

Much of the current Cape Cod 208 implementation is focused on estuary nitrogen TMDLs. It is uncertain what form compliance with these TMDLs will take (*e.g.*, water quality monitoring over how many years, measurements of restoration of eelgrass areas, etc.) and it is similarly unclear how freshwater ponds and their potential TMDLs will be integrated into overall water quality management. It is clear, however, that natural nitrogen removal within freshwater ponds was an integral part of most of the watershed analyses completed by the Massachusetts Estuaries Project (MEP). Better quantification of these removals and update of MEP-era results may offer opportunities to update and integrate water quality management of both estuaries and pond.

VI. Conclusions

Water quality monitoring of 11 Dennis ponds and lakes has provided the Town with reliable information that can be used to develop management strategies for protecting and restoring these important, selected resources. Some of the ponds have been identified as impaired based on the data review and recommendations have been prepared for additional targeted data collection (outside of the usual volunteer collection) that will be necessary to develop reliable management plans to address the impairments. Based on the data review, other ponds are slightly impaired with transitional conditions that are slowly moving toward fully impaired conditions. It is generally recommended that the Town continue to monitoring the conditions in these ponds and review their status on a regular basis. Targeted data collection recommendations are included if the Town decides to pursue more active management for these ponds. Additional recommendations for future water quality management integrated among ponds and estuaries and TMDL compliance are also provided.

CSP/SMASST staff continues to be available to the Town of Dennis to help implement and refine these recommendations.

VII. References

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APPENDIX A

Pond Water Quality Graphs Town of Dennis Pond Water Quality Database

Time-series data are presented from 2001 through 2015, including all PALS Snapshot data. Graphs are presented in the following order: temperature, dissolved oxygen, Secchi/clarity and station depth, pH, chlorophyll, and total phosphorus. Graphs also include available MassDEP surface water regulatory limits (314 CMR 4) or Cape Cod-specific guidance limit concentrations developed using the 2001 PALS Snapshot results and an EPA guidance concentration calculation method (Eichner, *et al.*, 2003). Presented data have outliers removed.

Ponds

Bakers

Cedar

Coles

Eagle

Flax

Fresh

Hiram

North Simmons

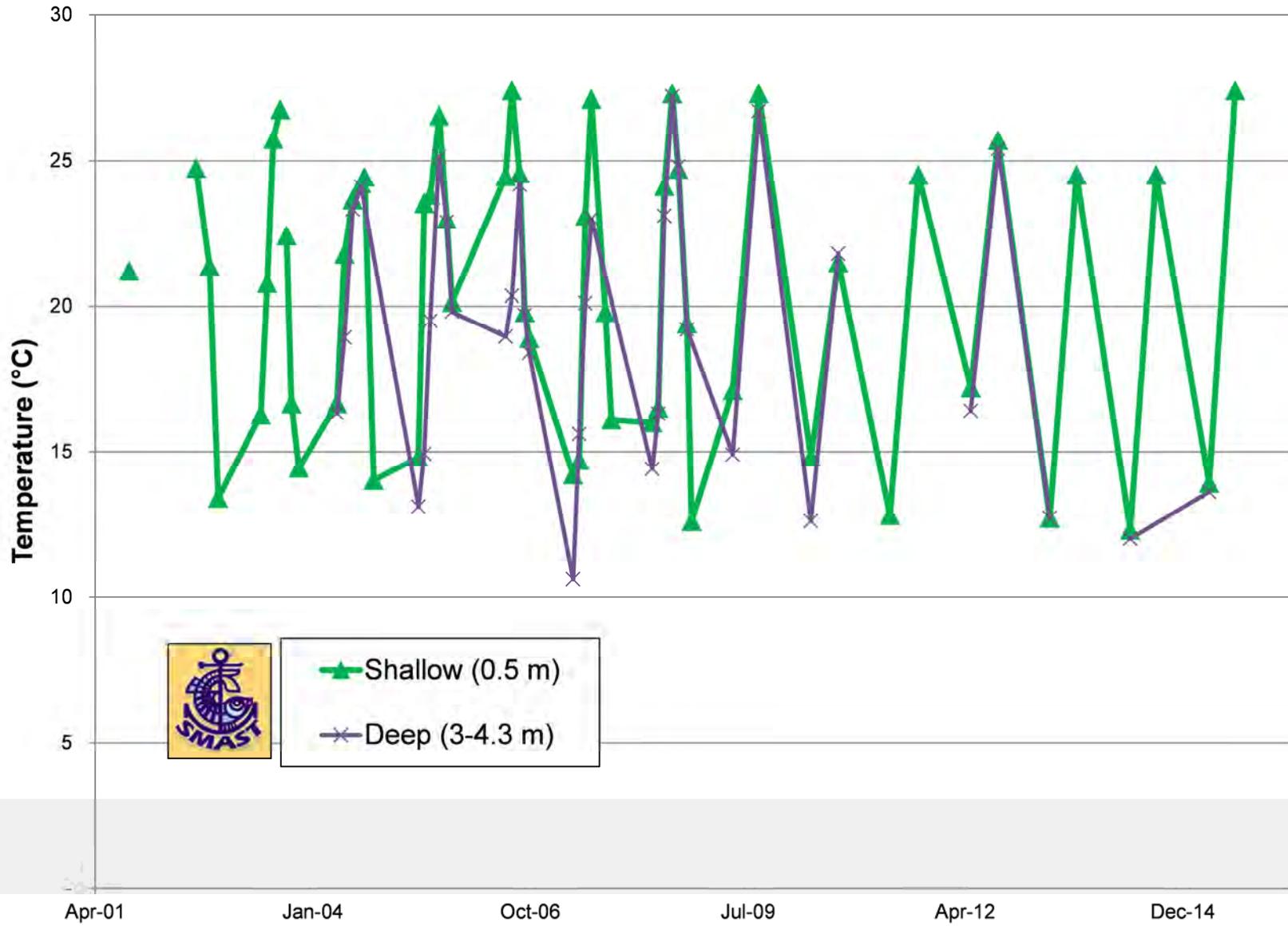
Run

Scargo

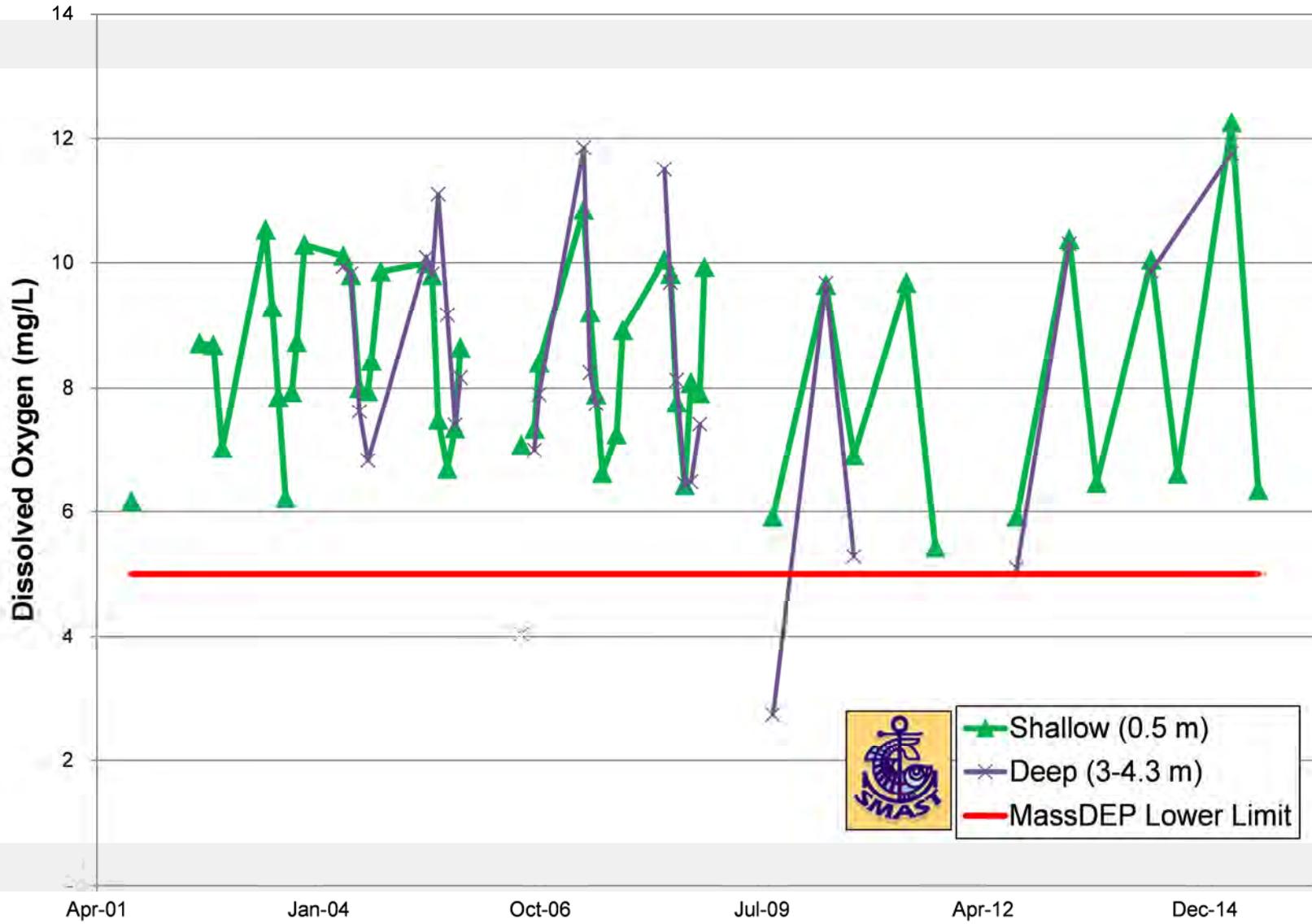
Whites

Bakers Pond

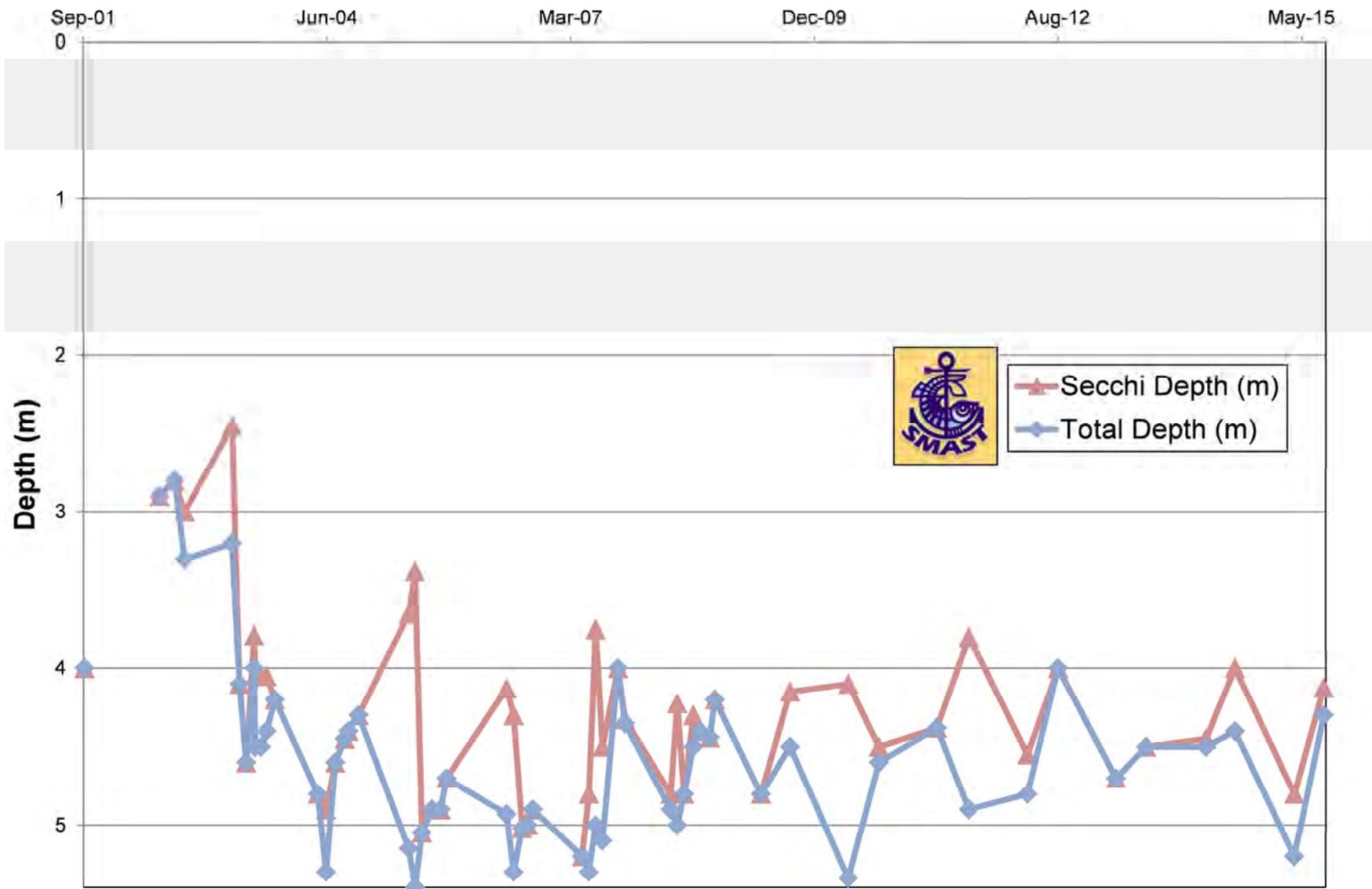
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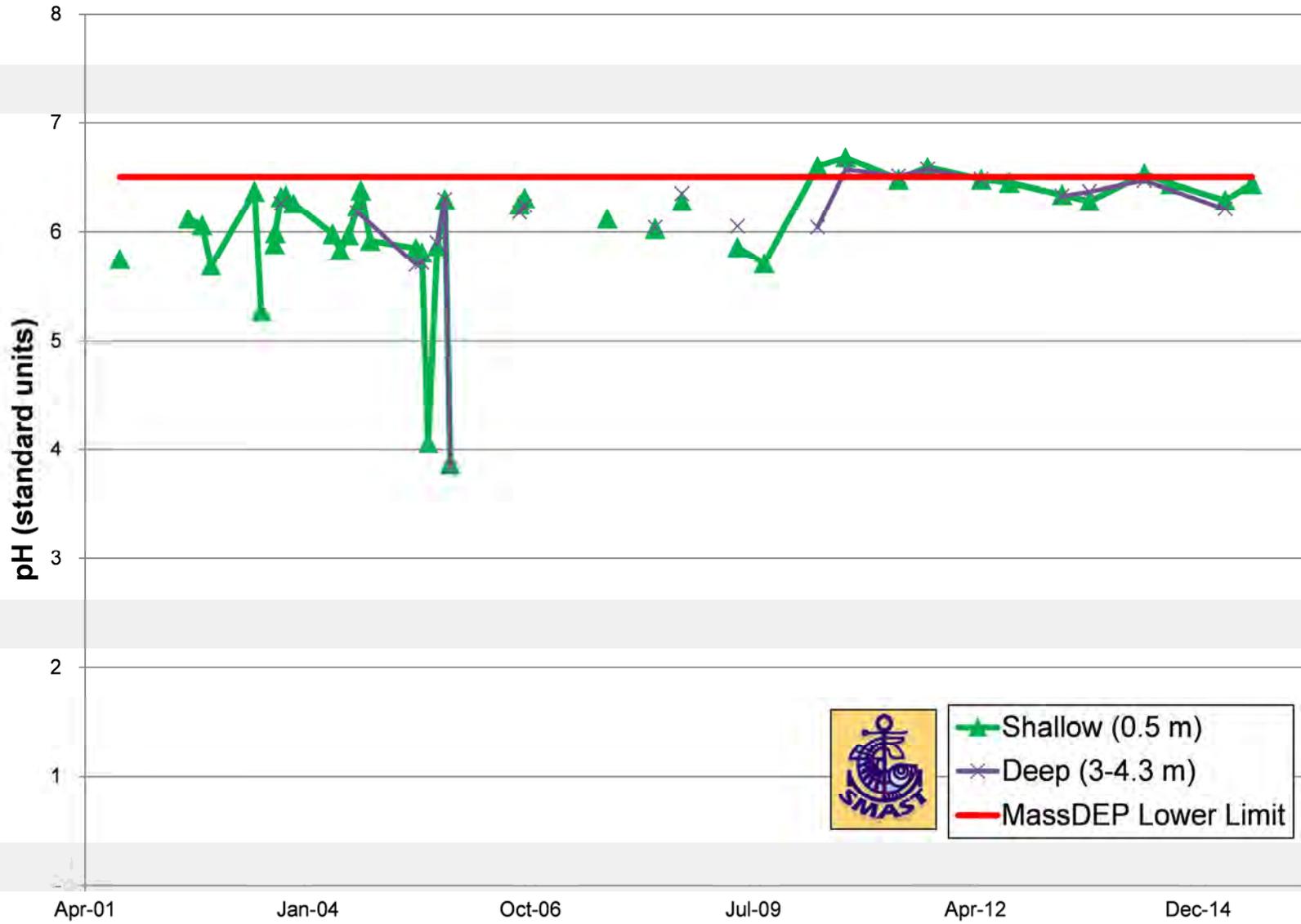
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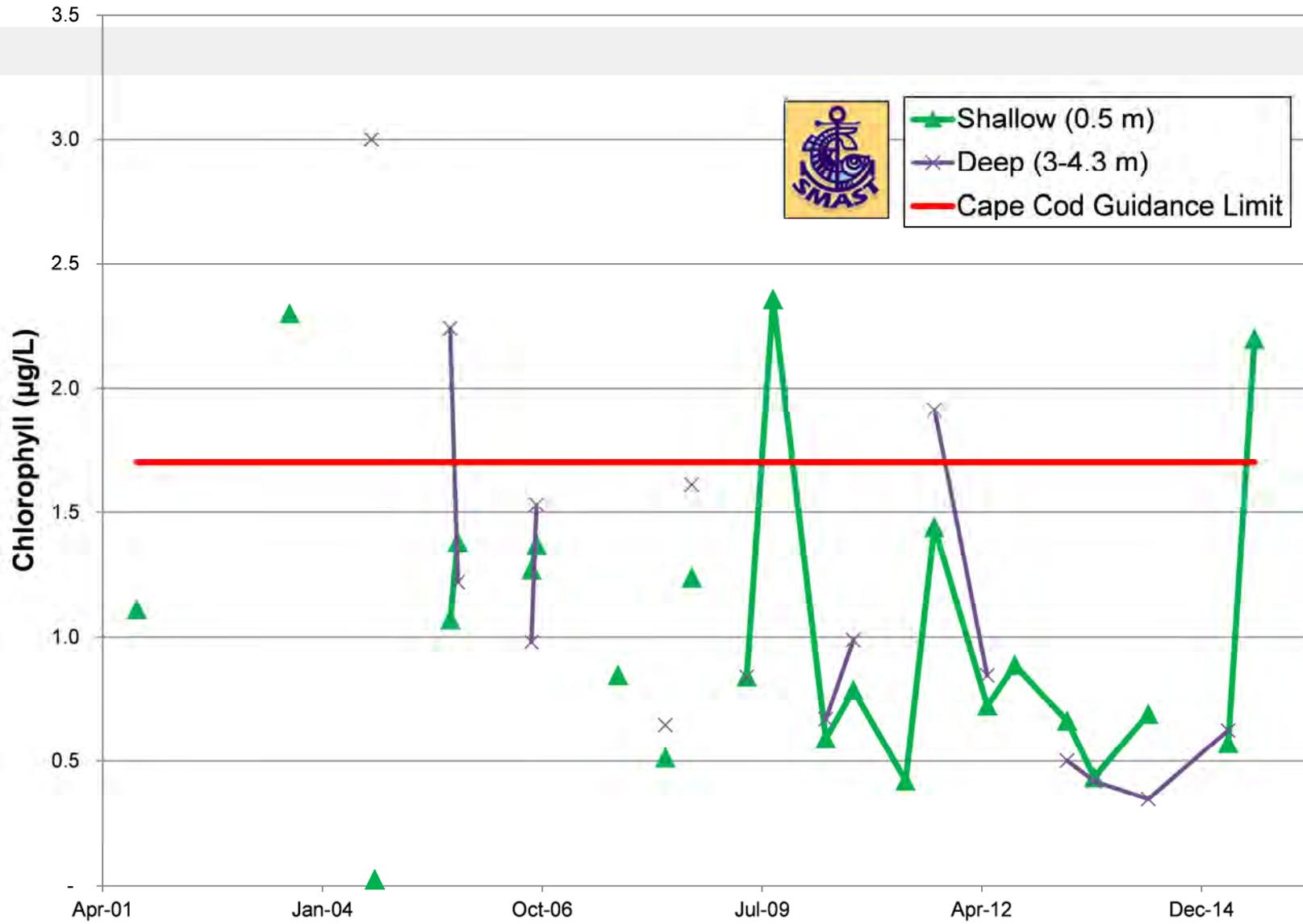
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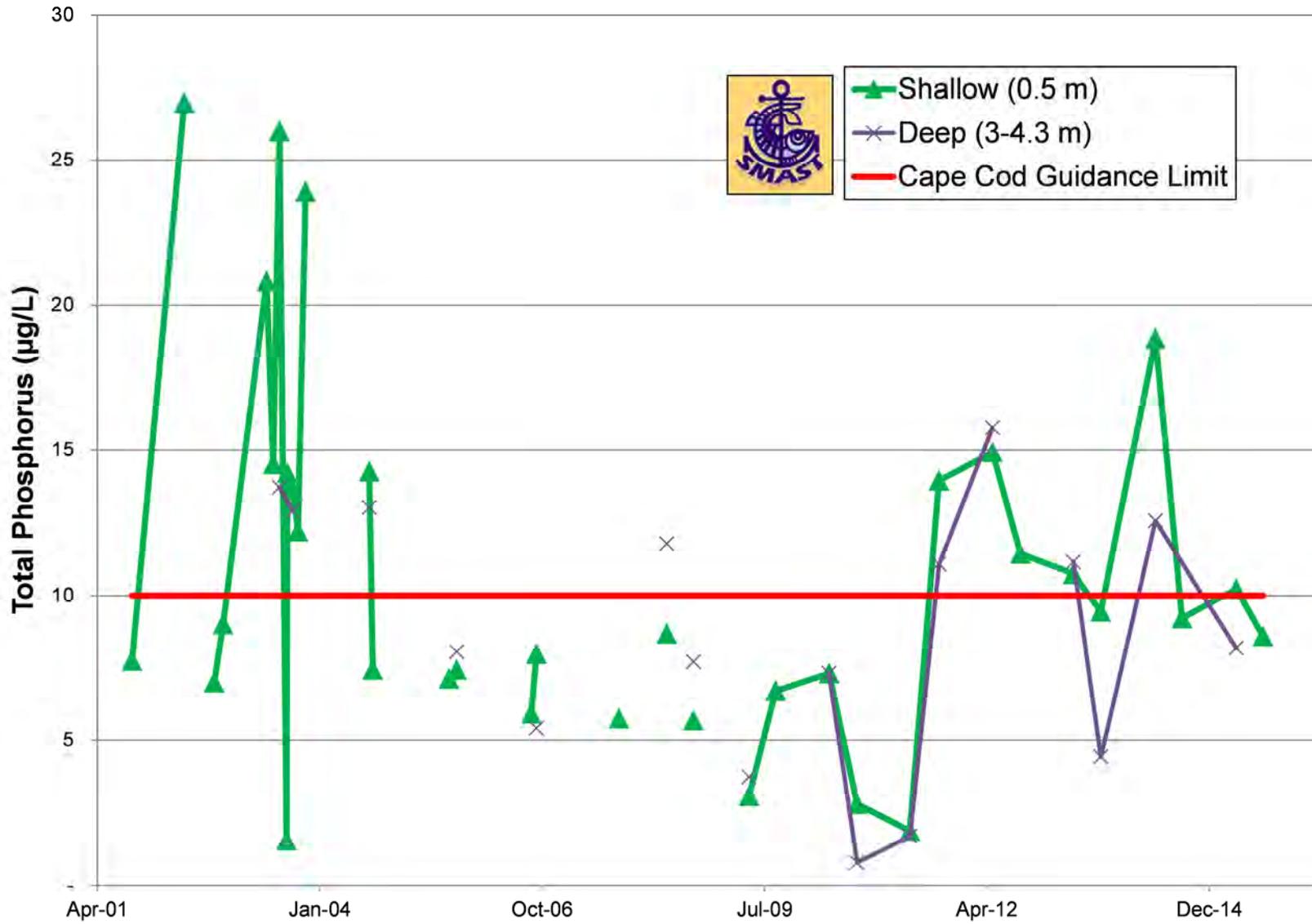
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Bakers Pond: Dennis

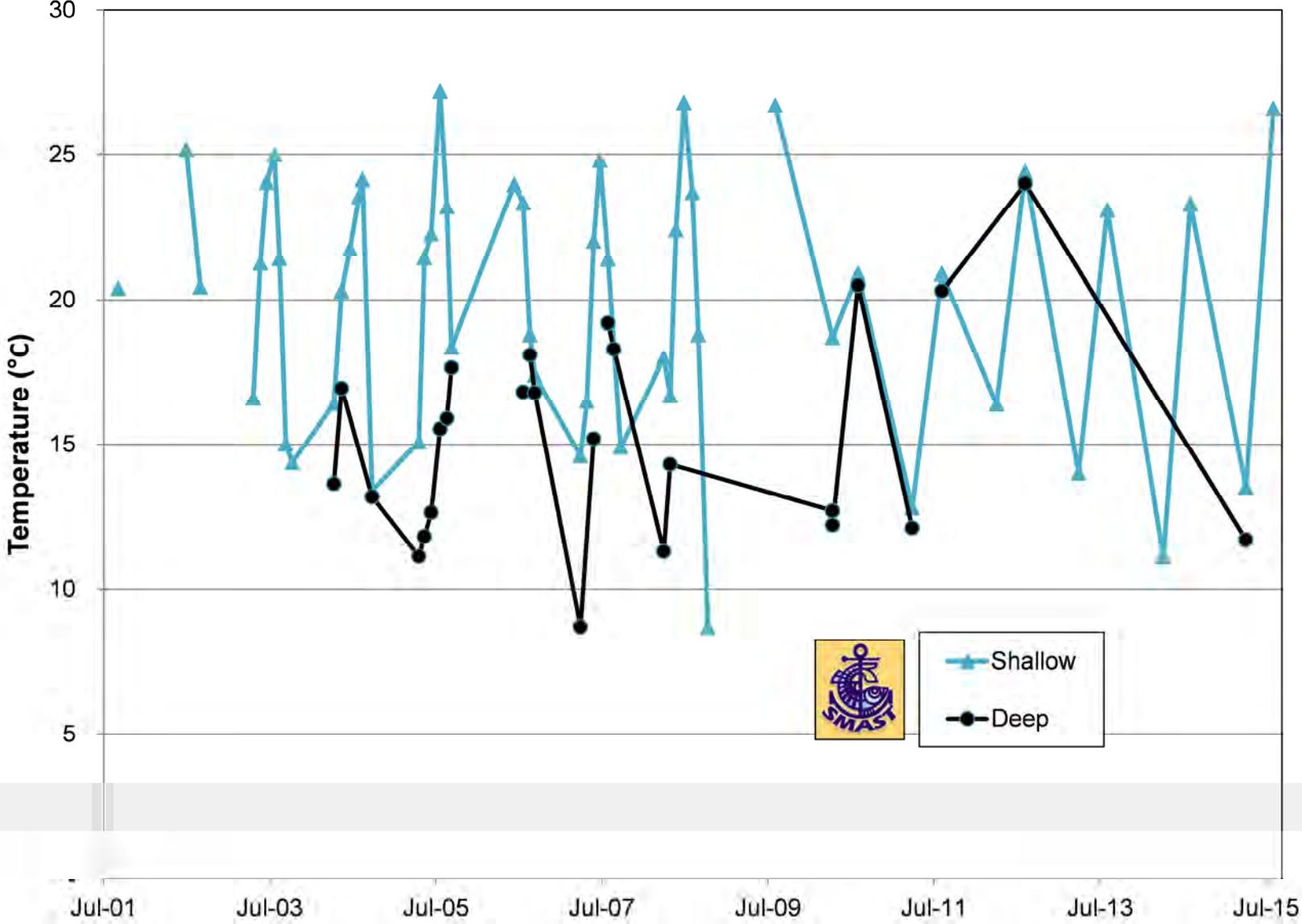


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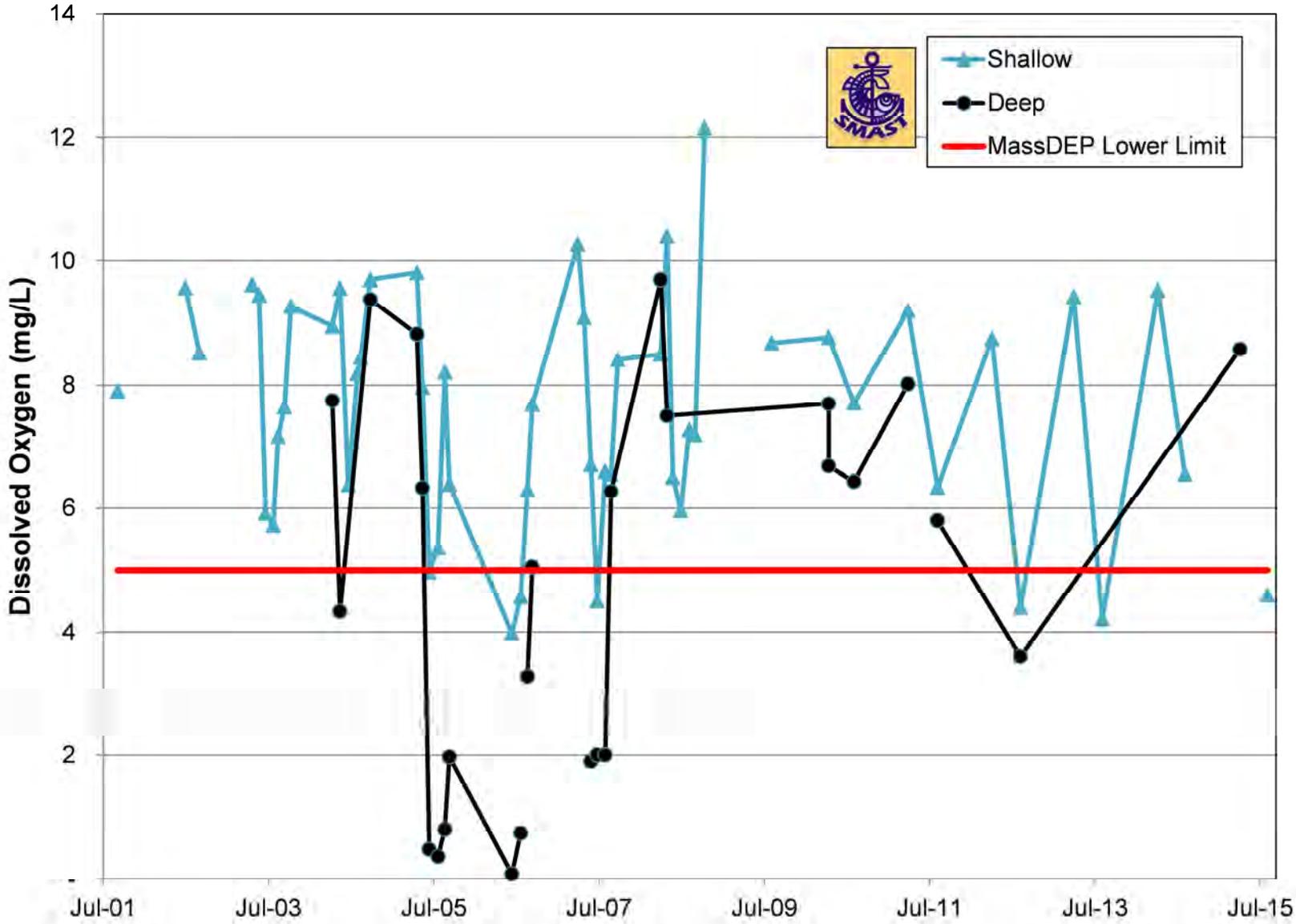


Cedar Pond

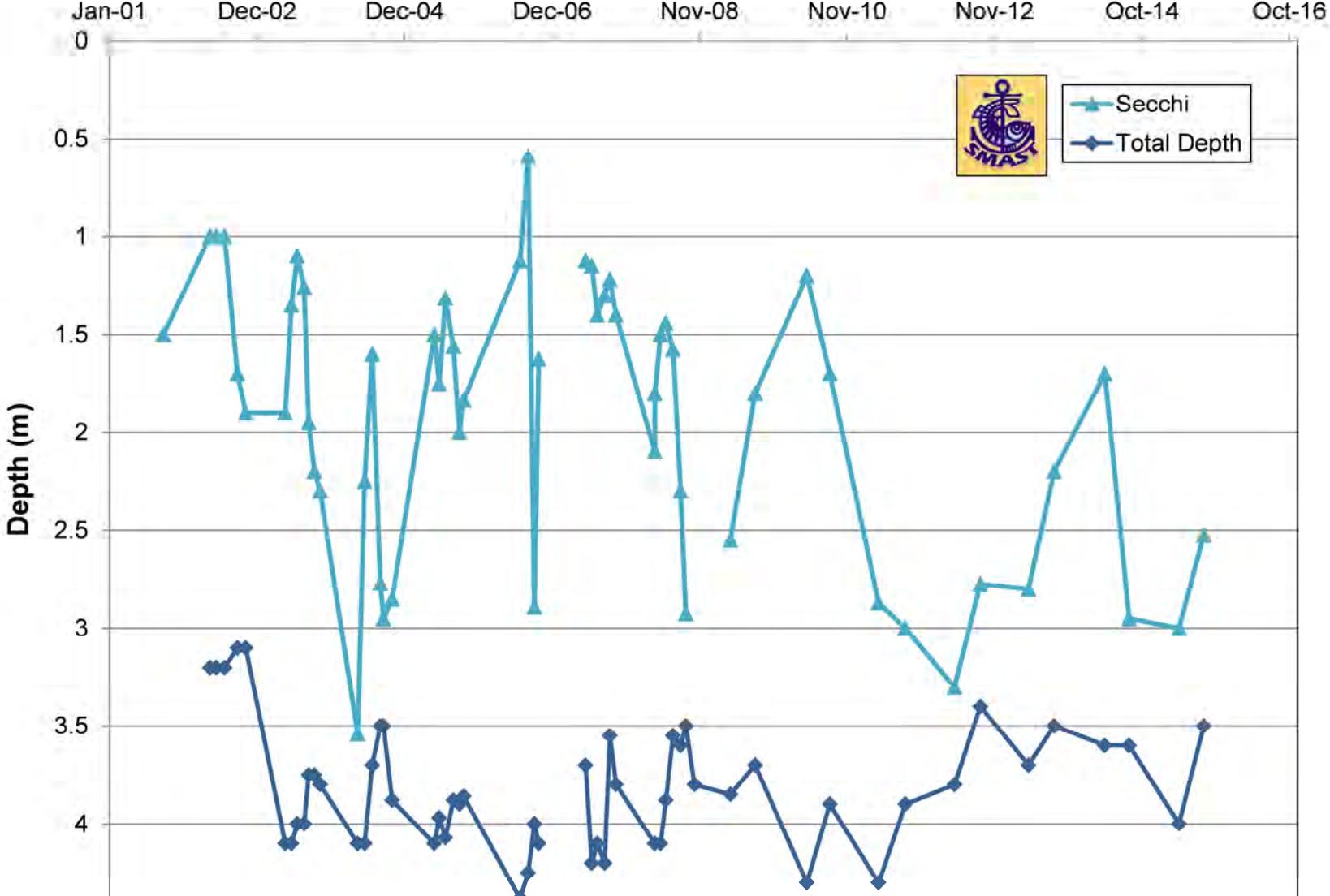
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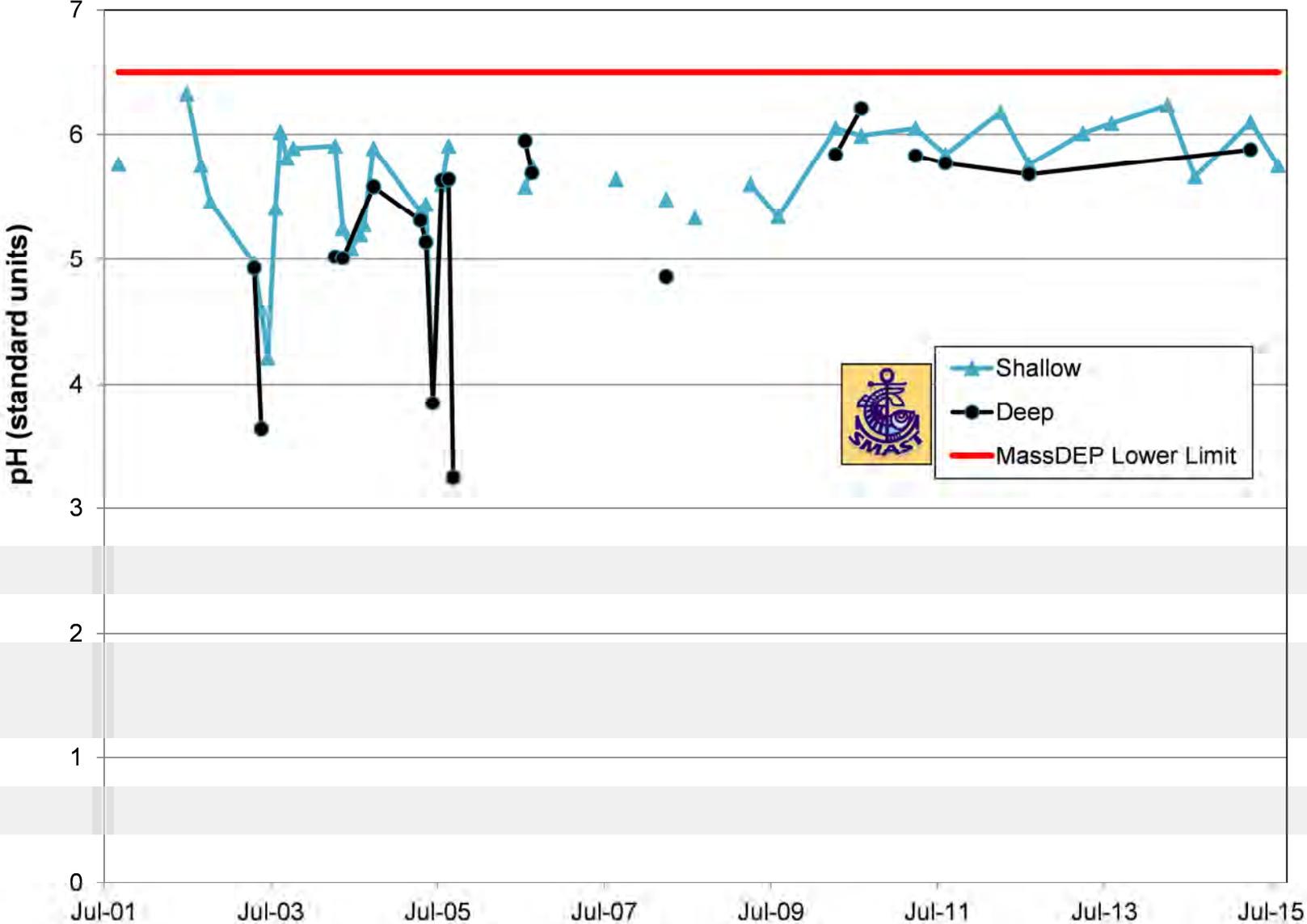
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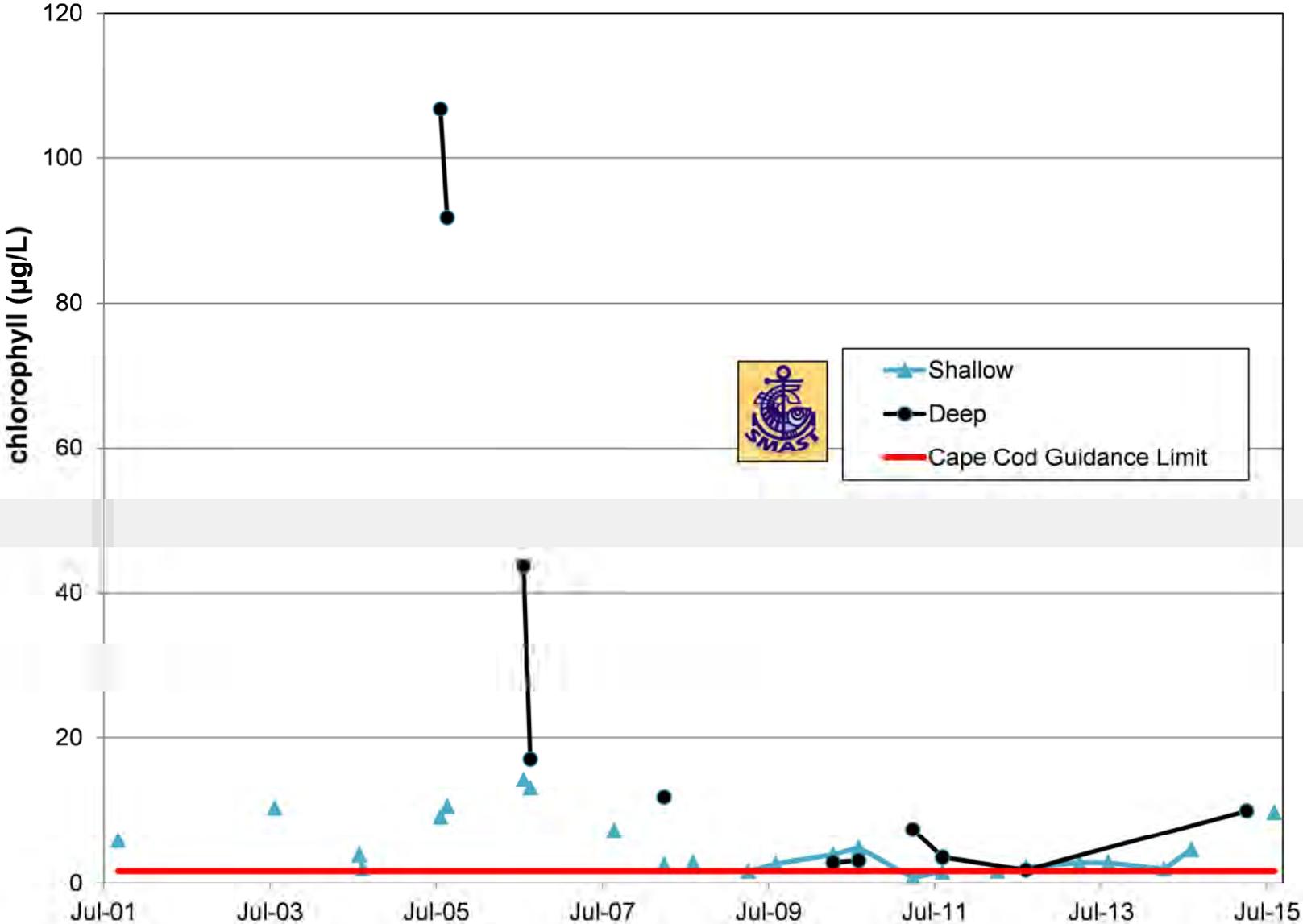
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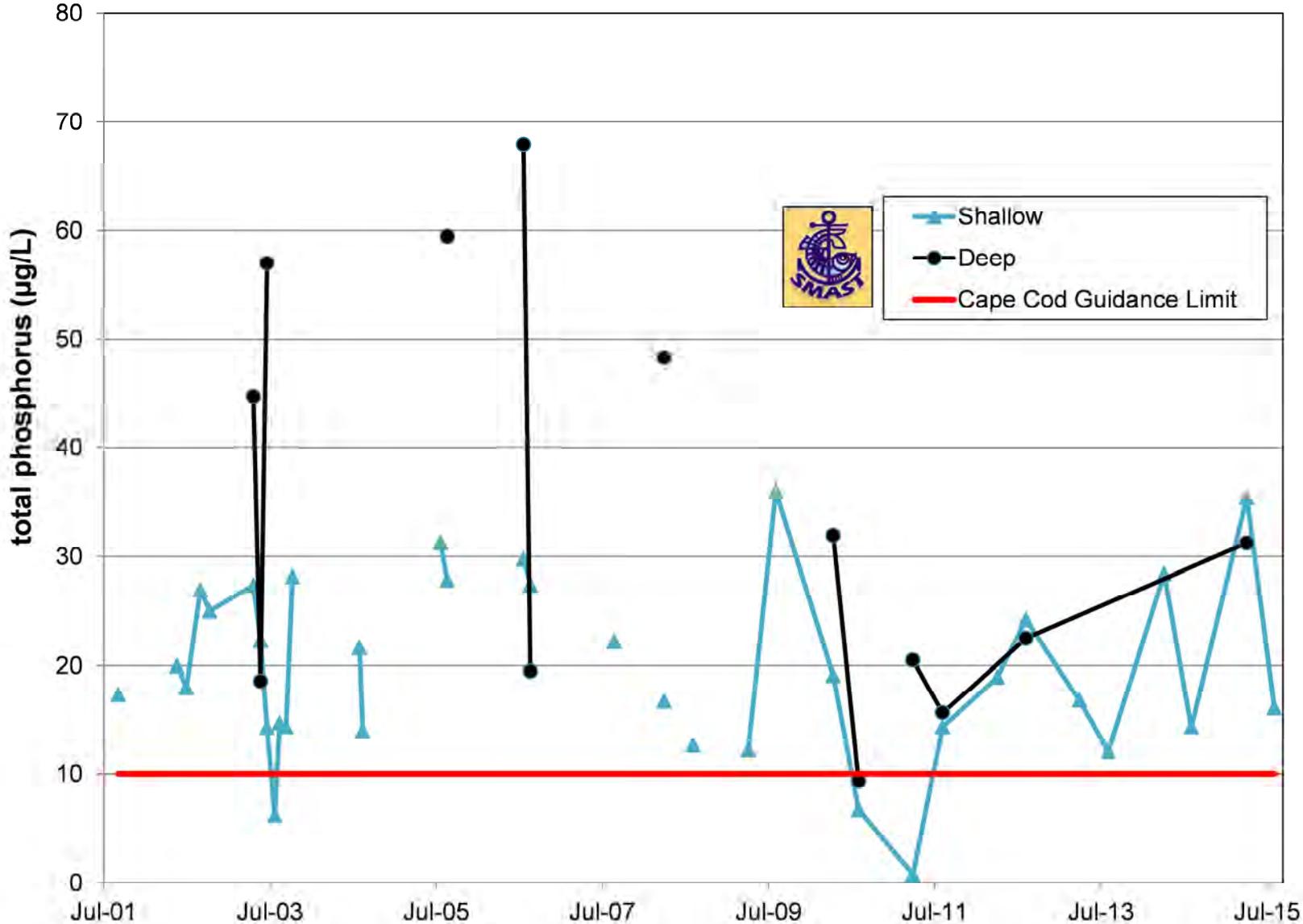
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Cedar Pond: Dennis

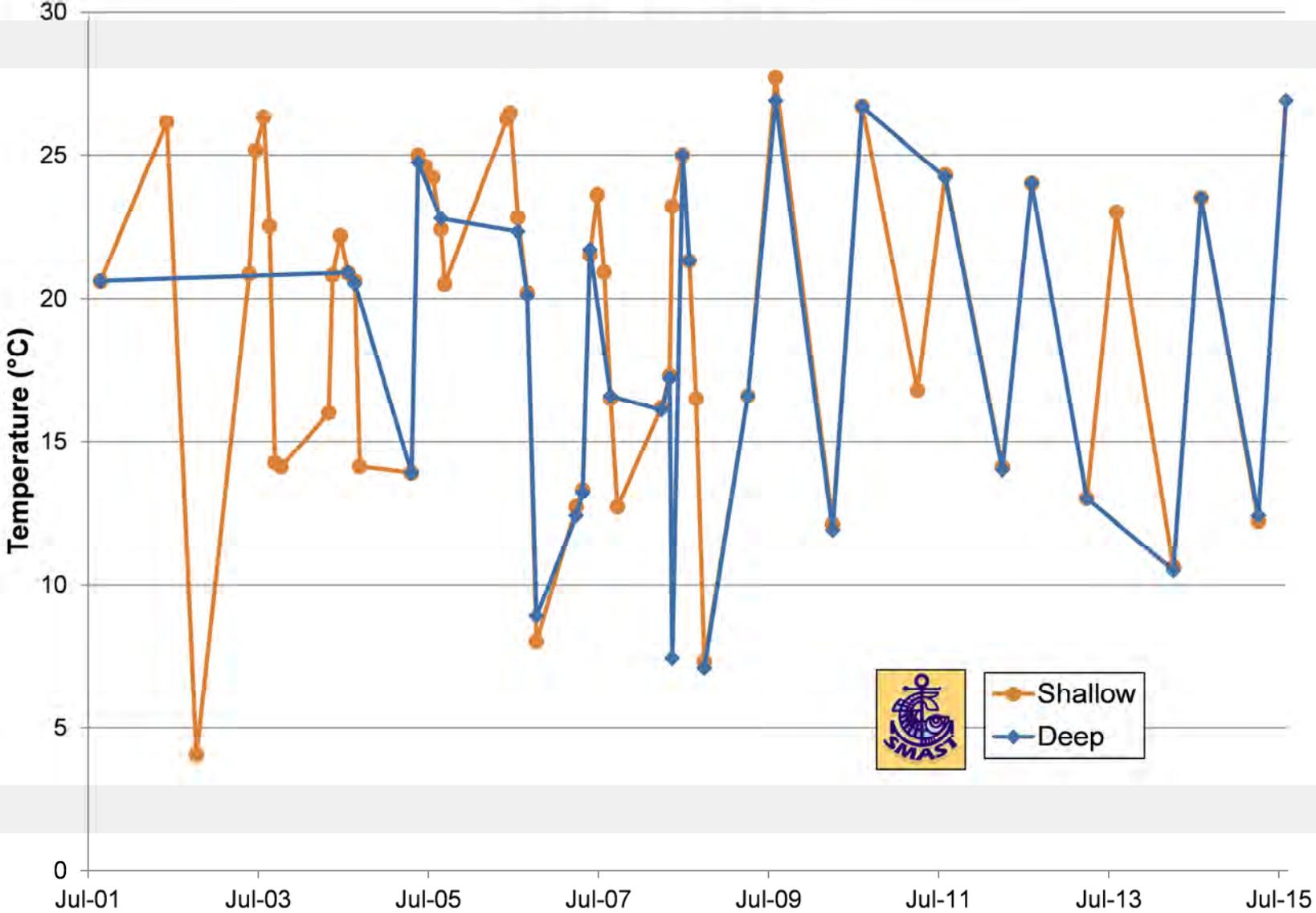


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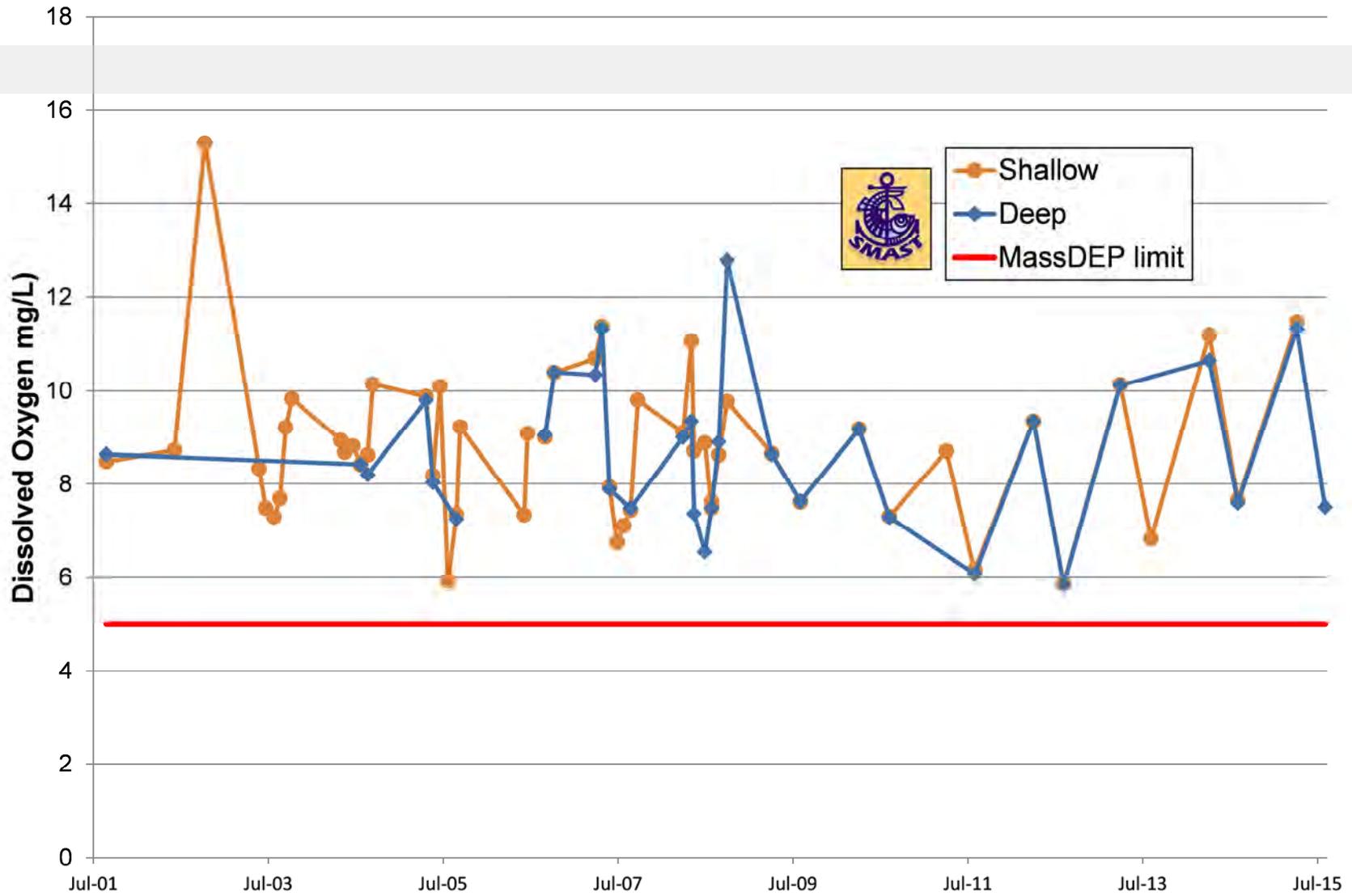
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Coles Pond: Dennis

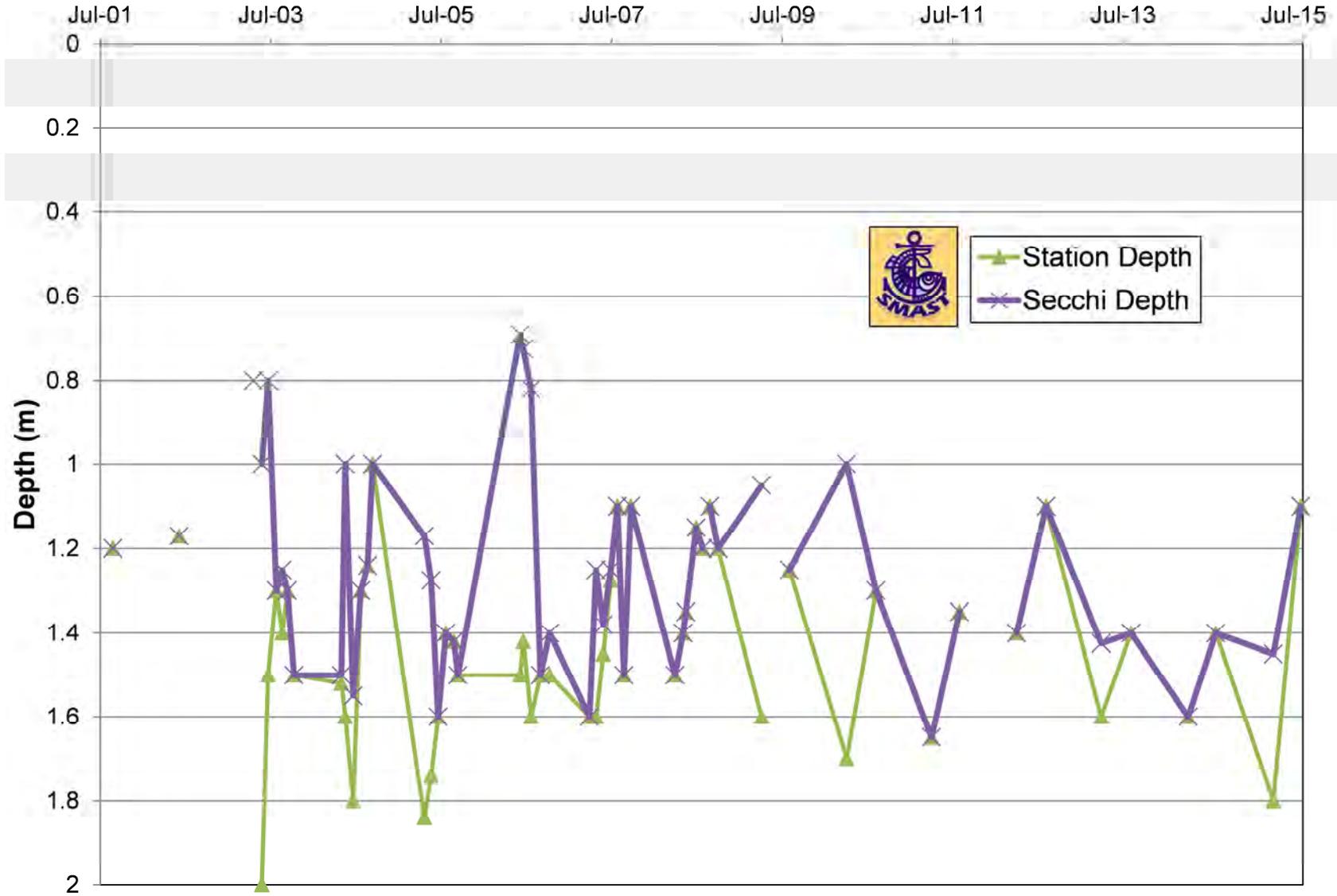


Shallow
Deep

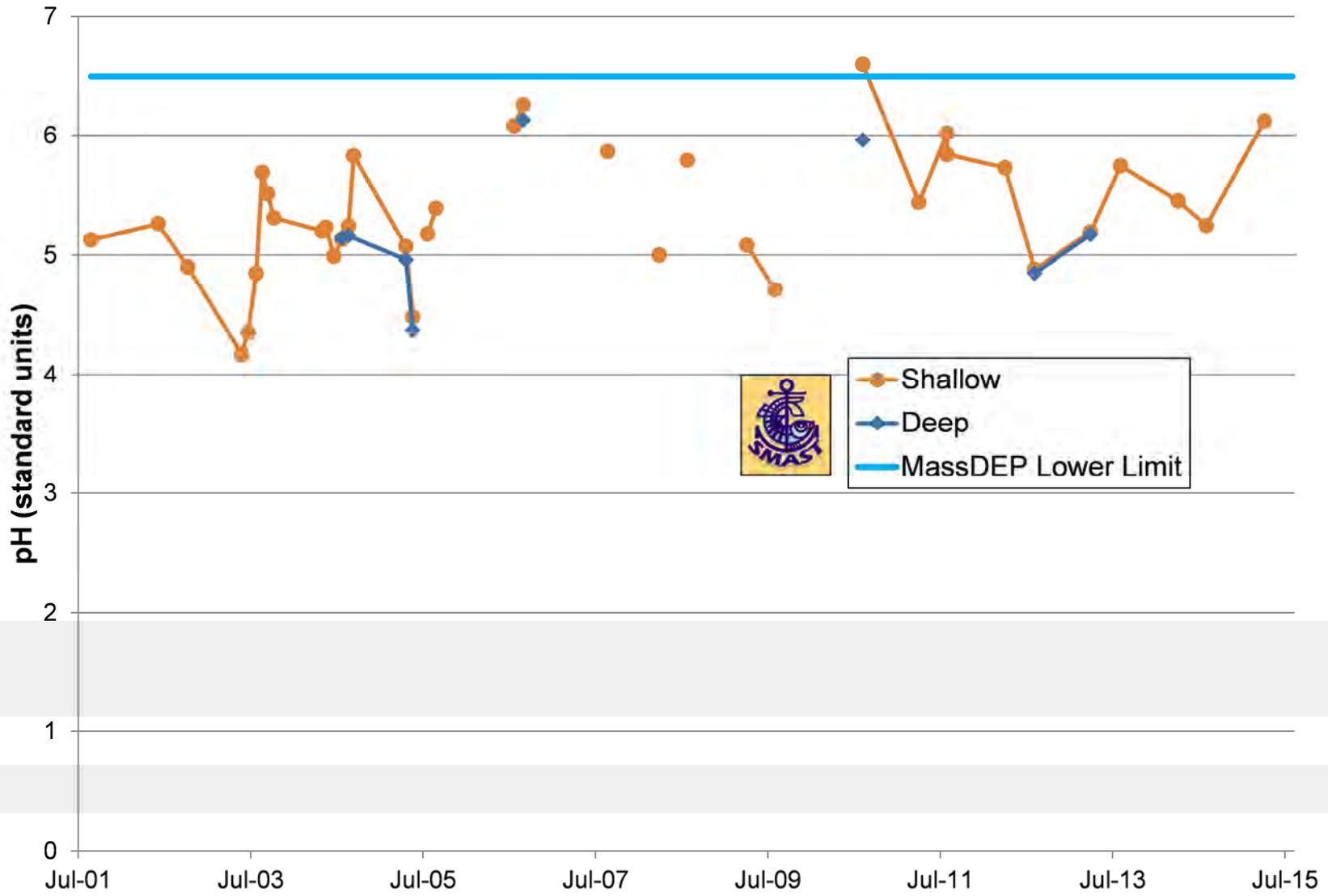
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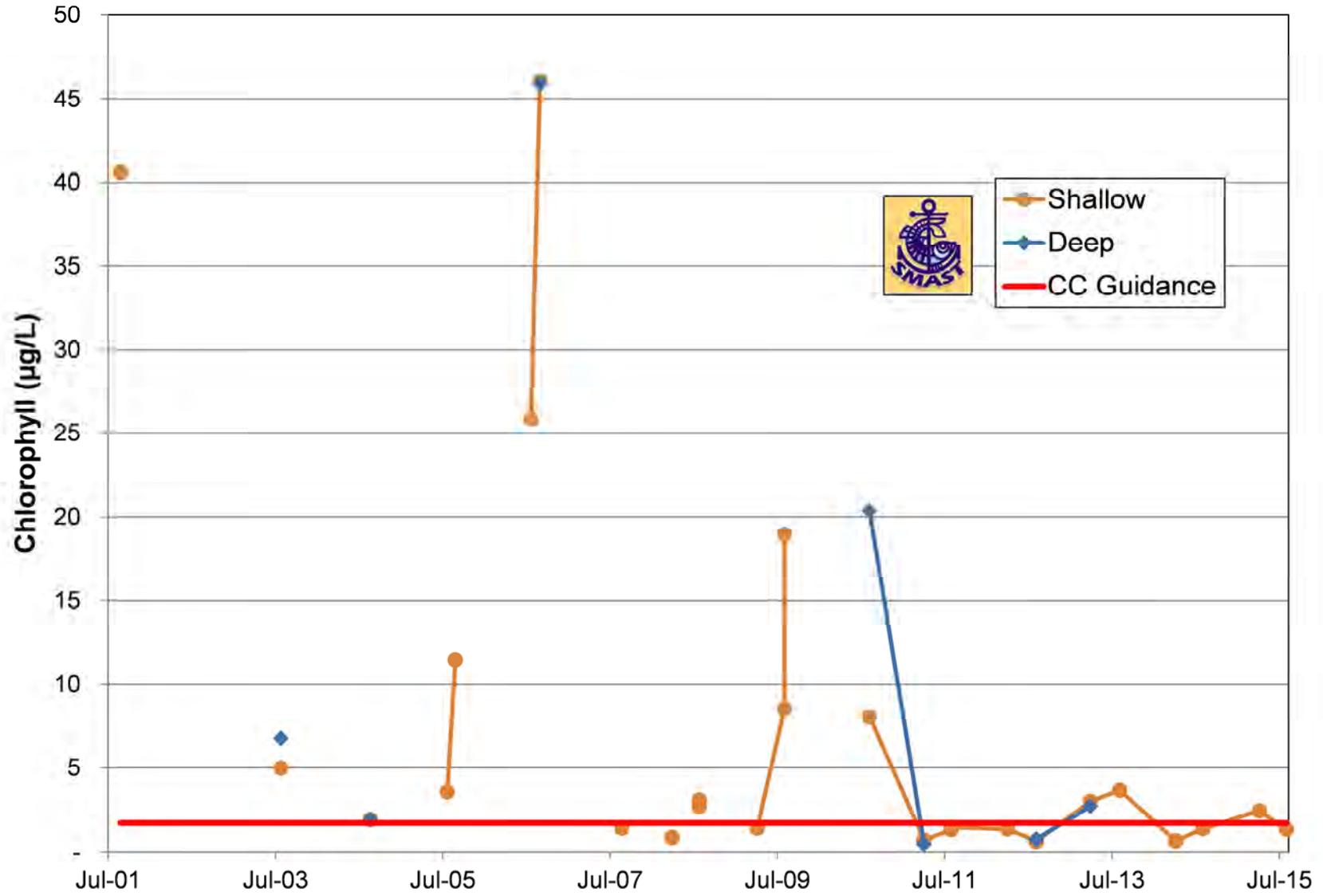
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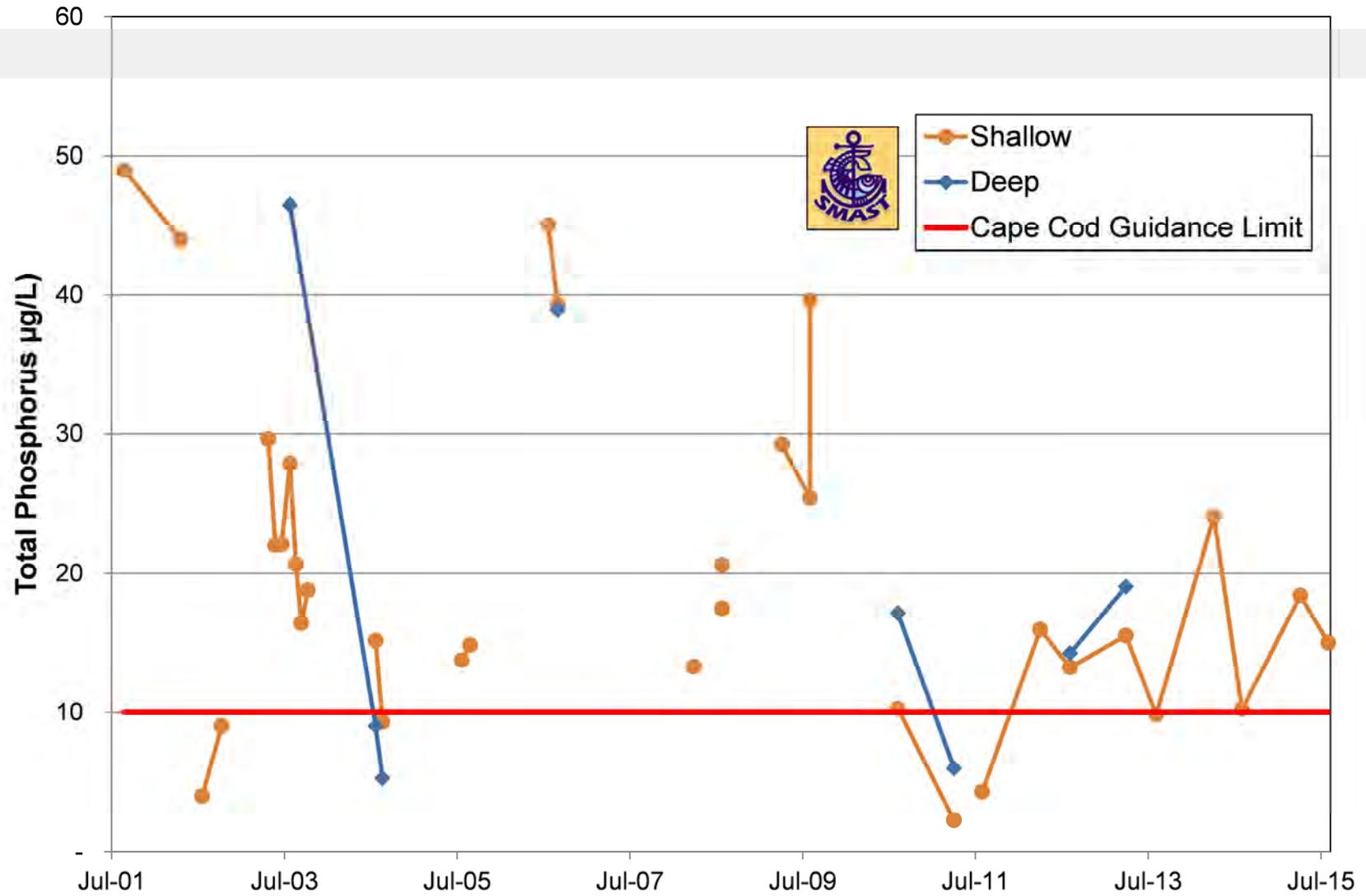
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Coles Pond: Dennis

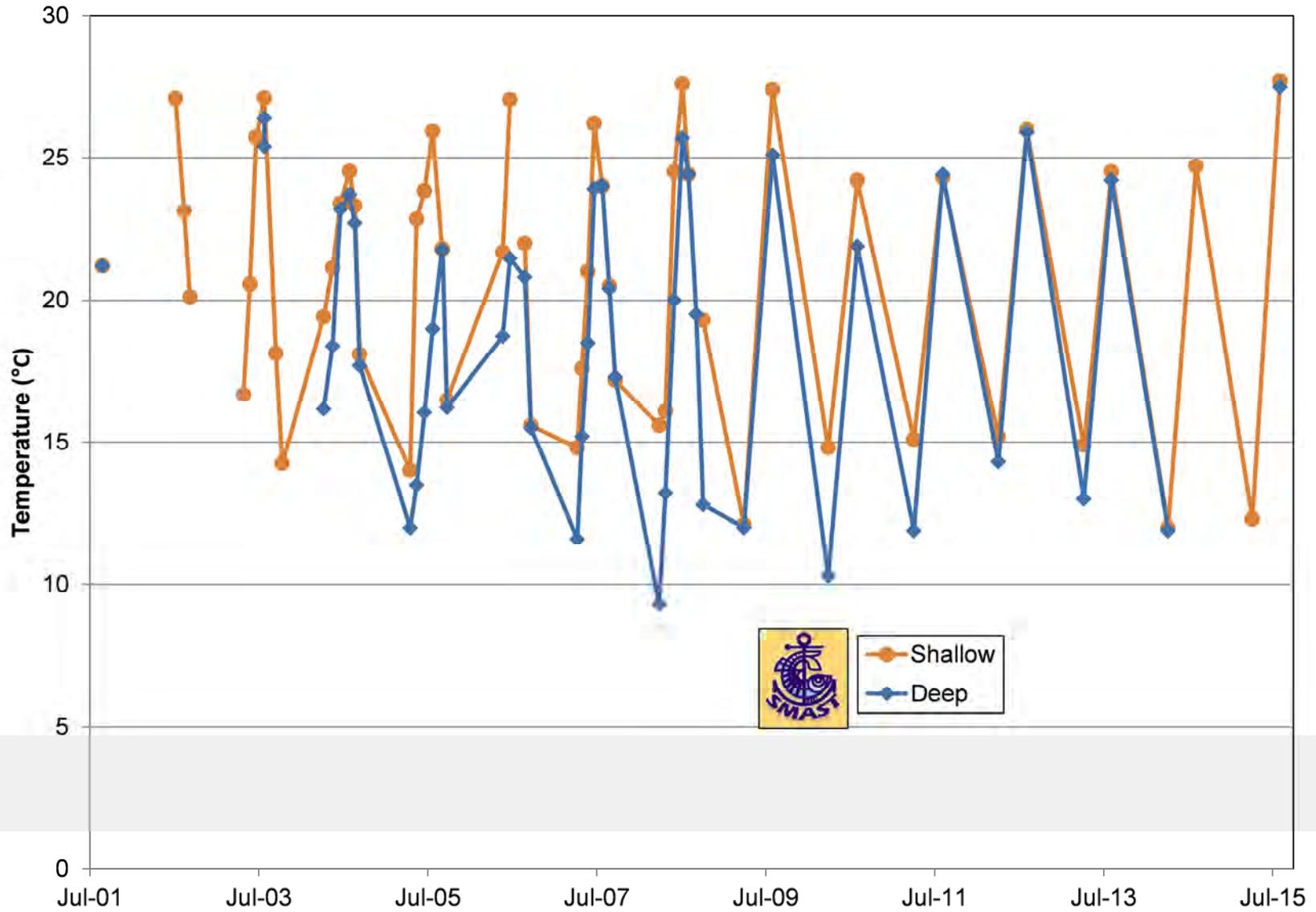


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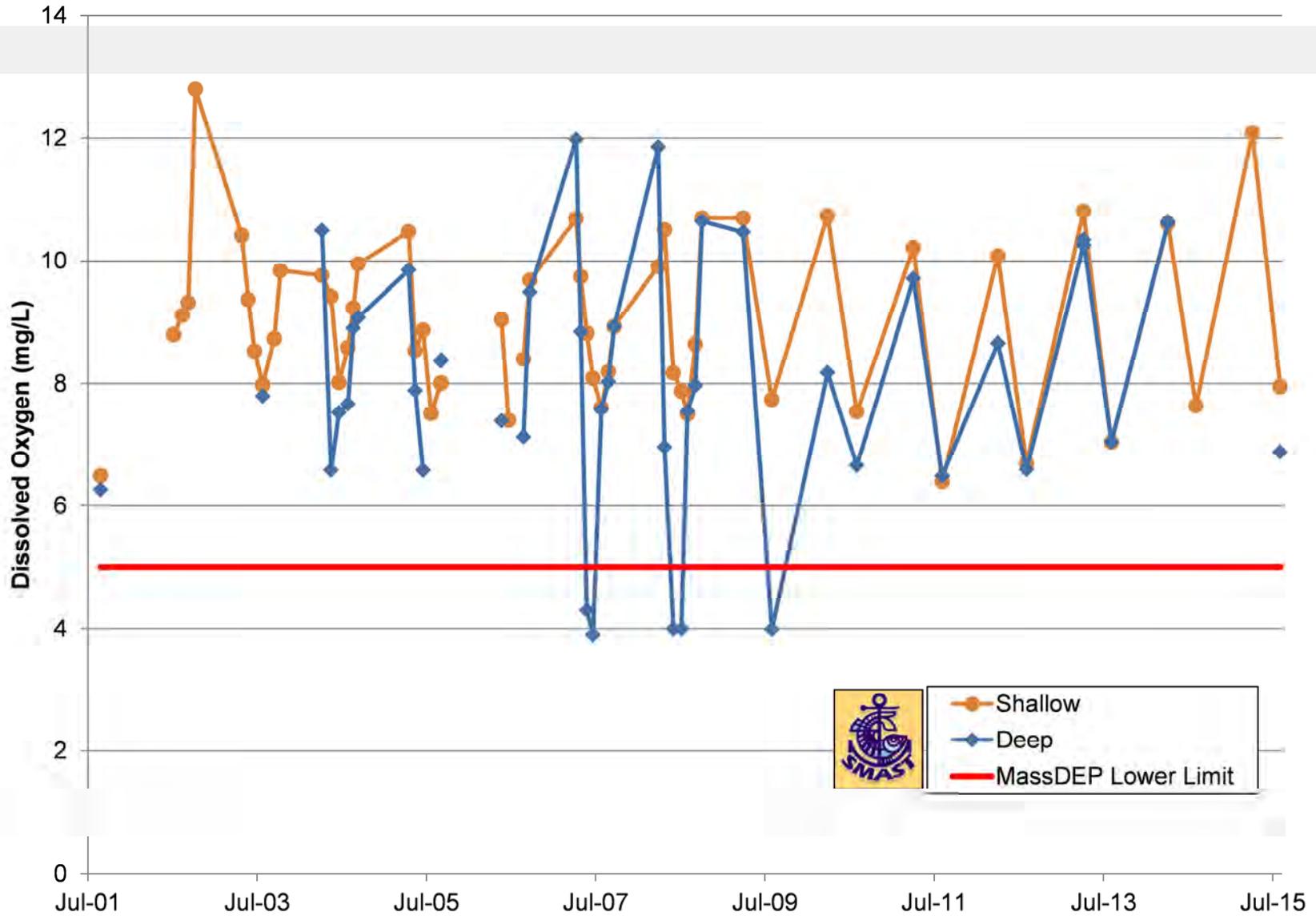


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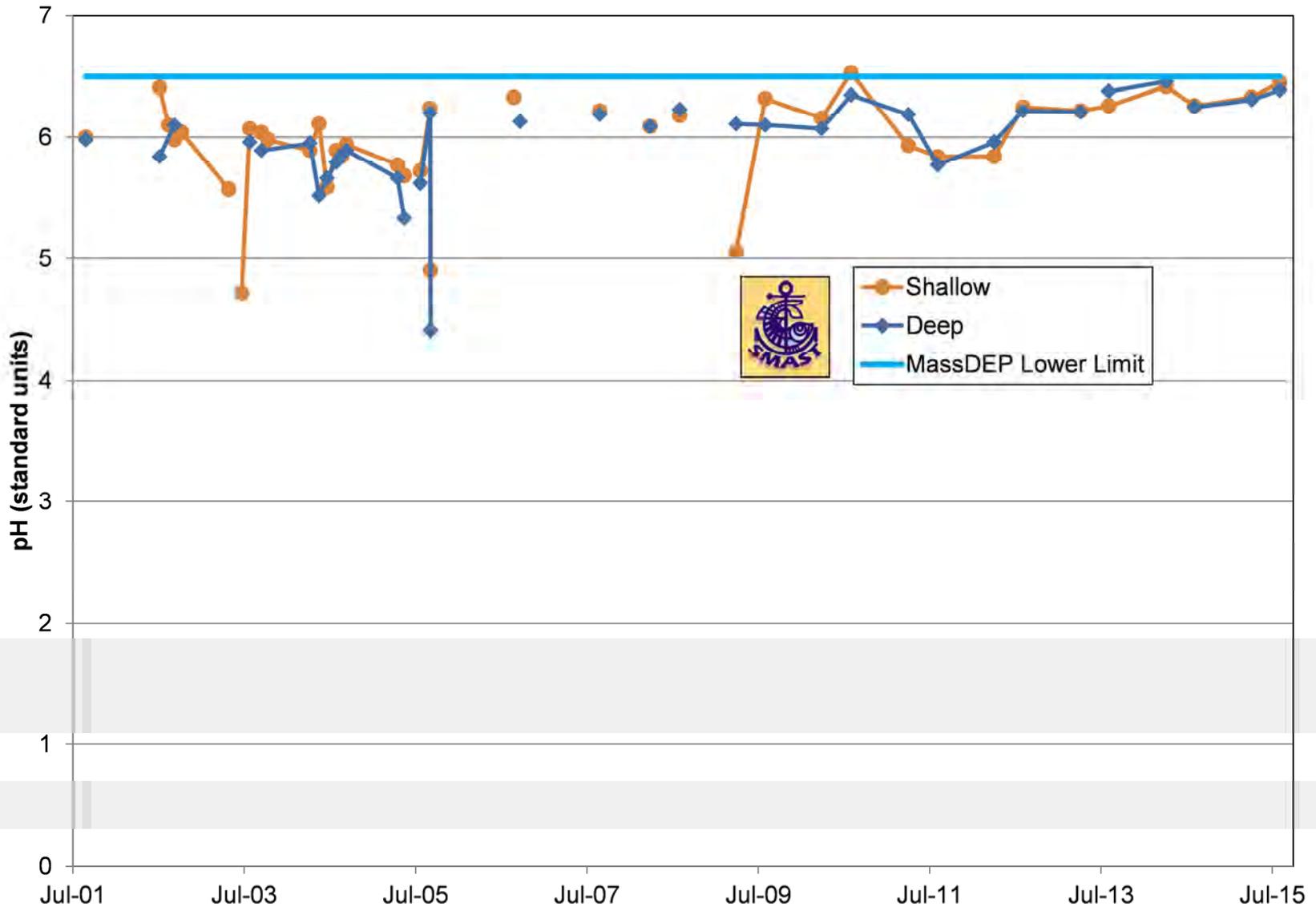
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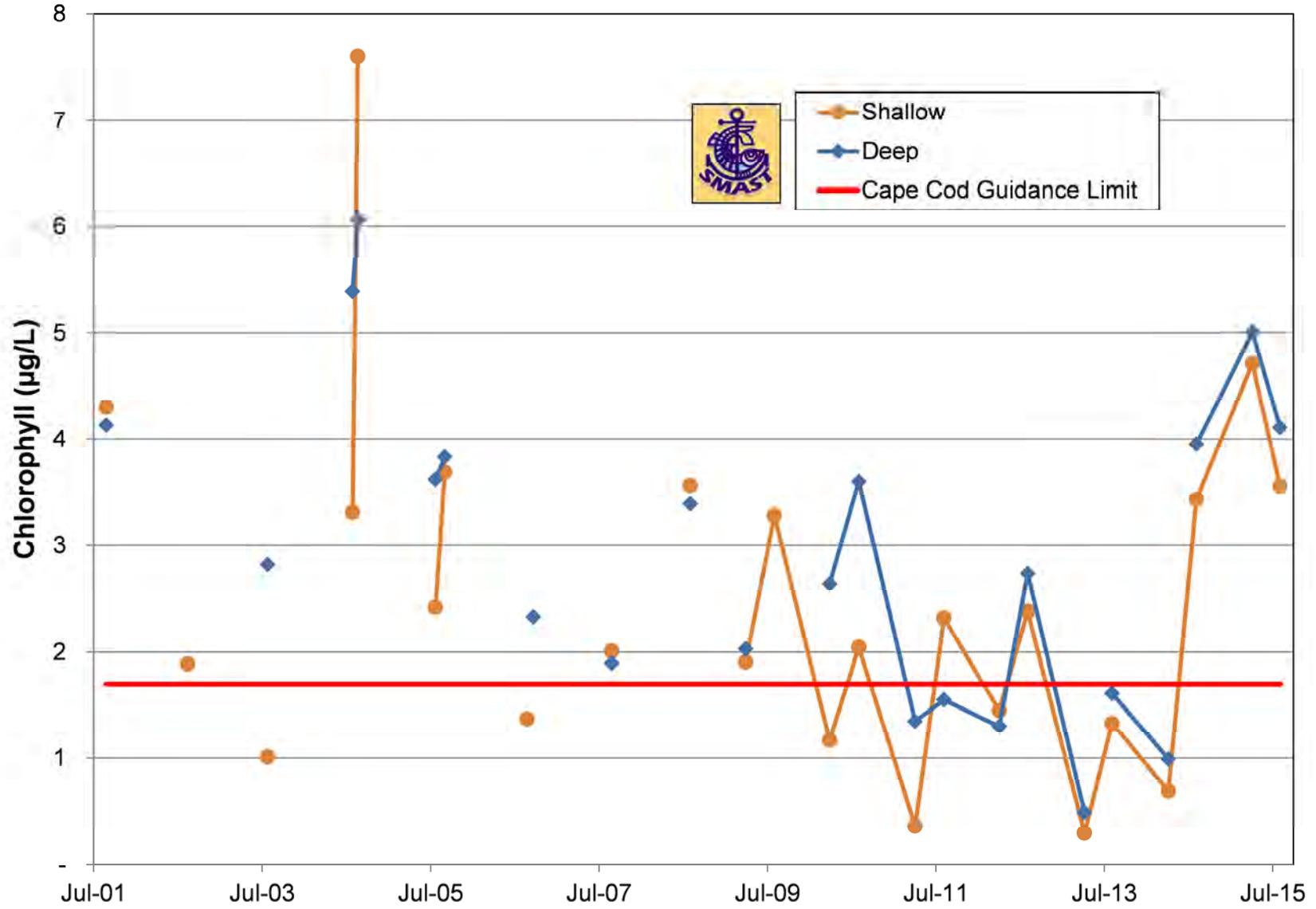
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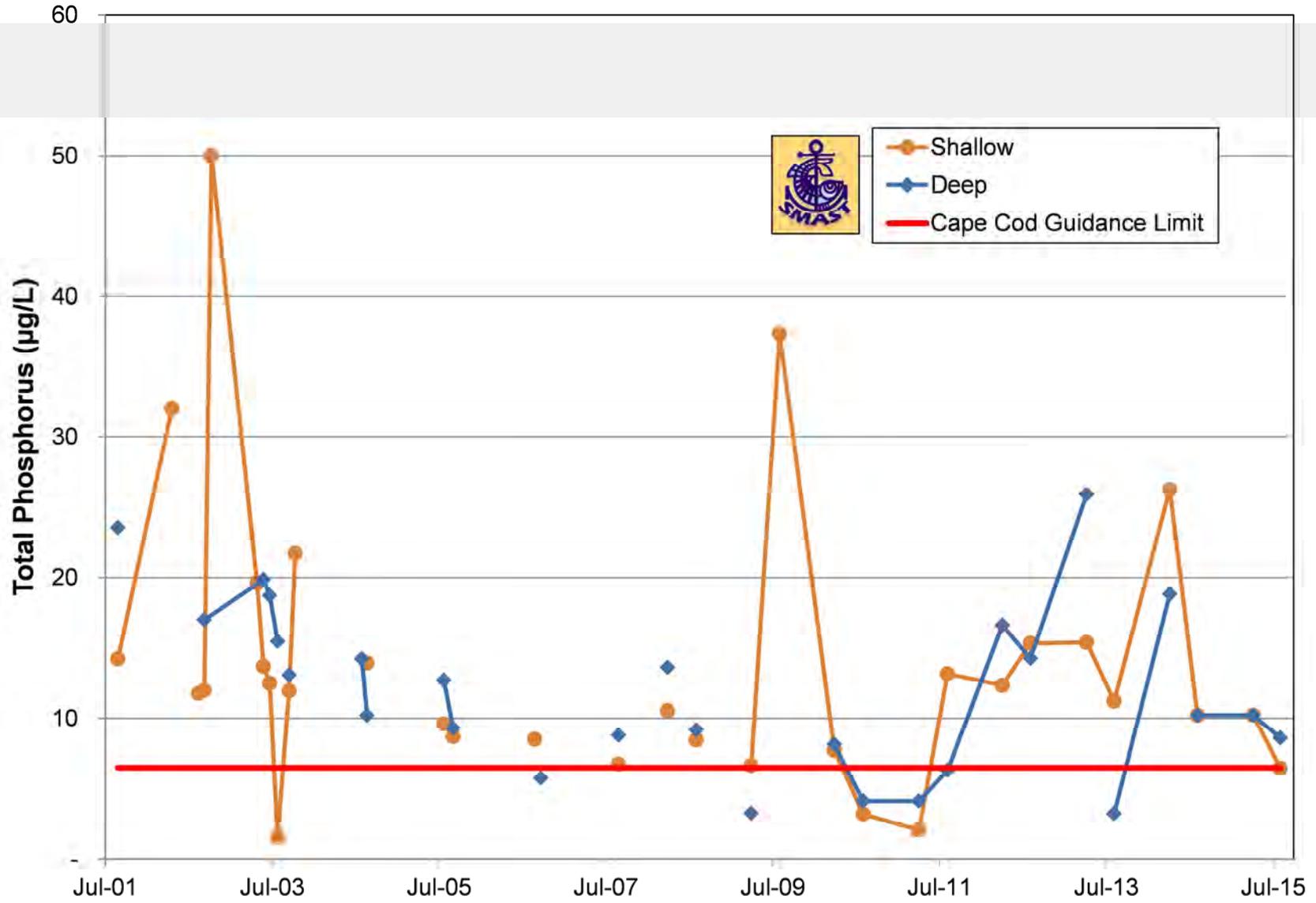
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Eagle Pond: Dennis

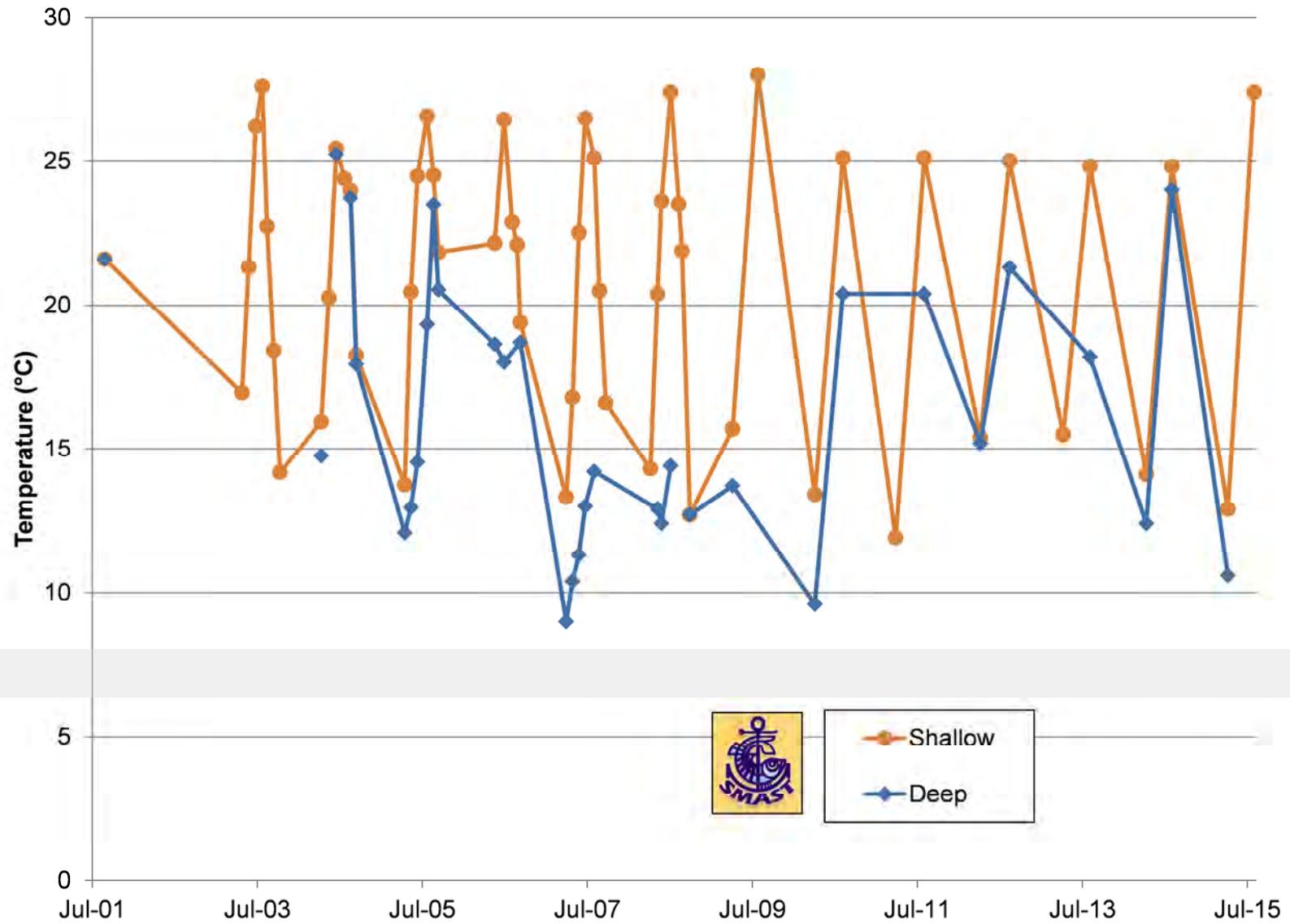


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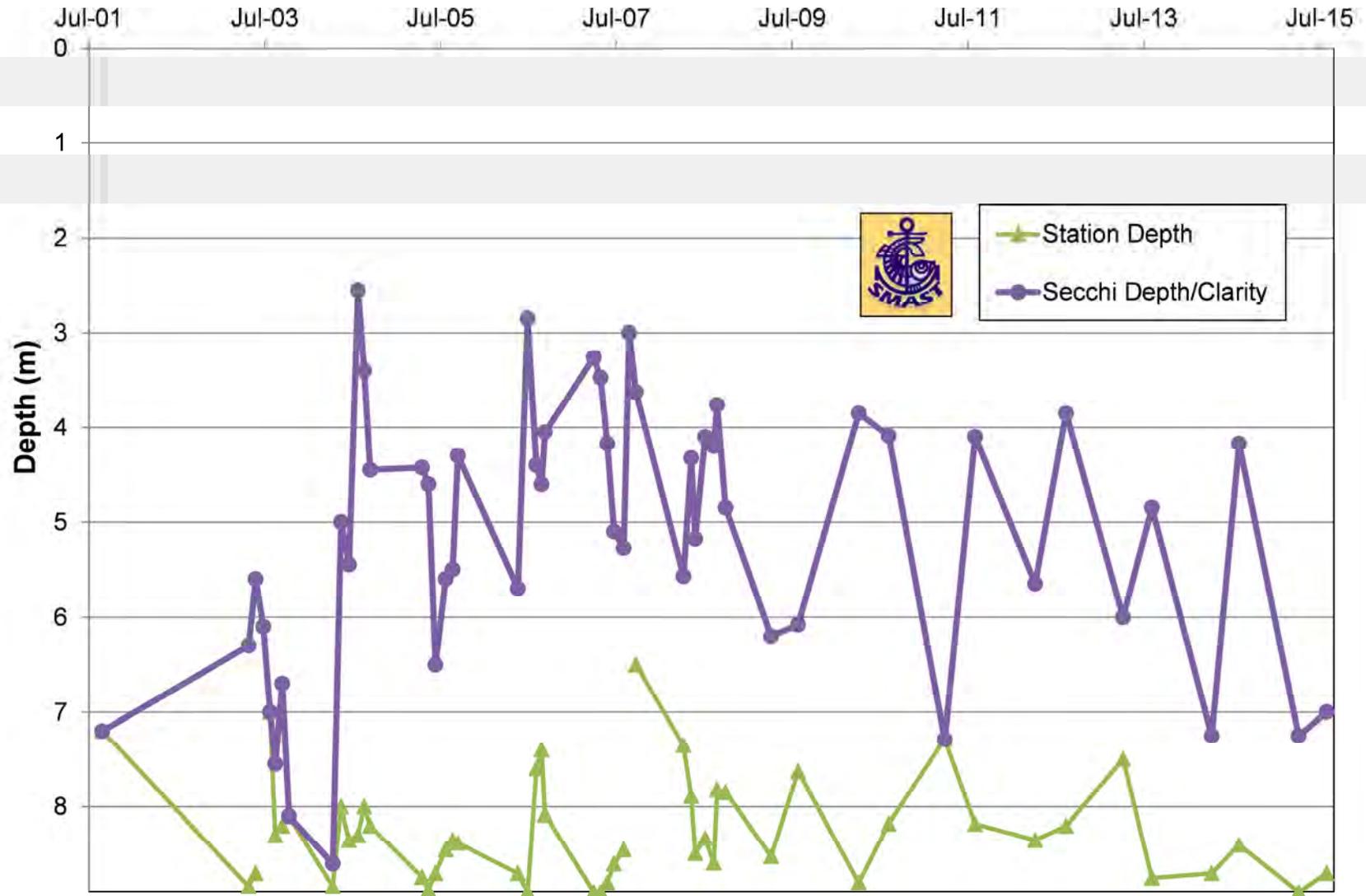


Flax Pond

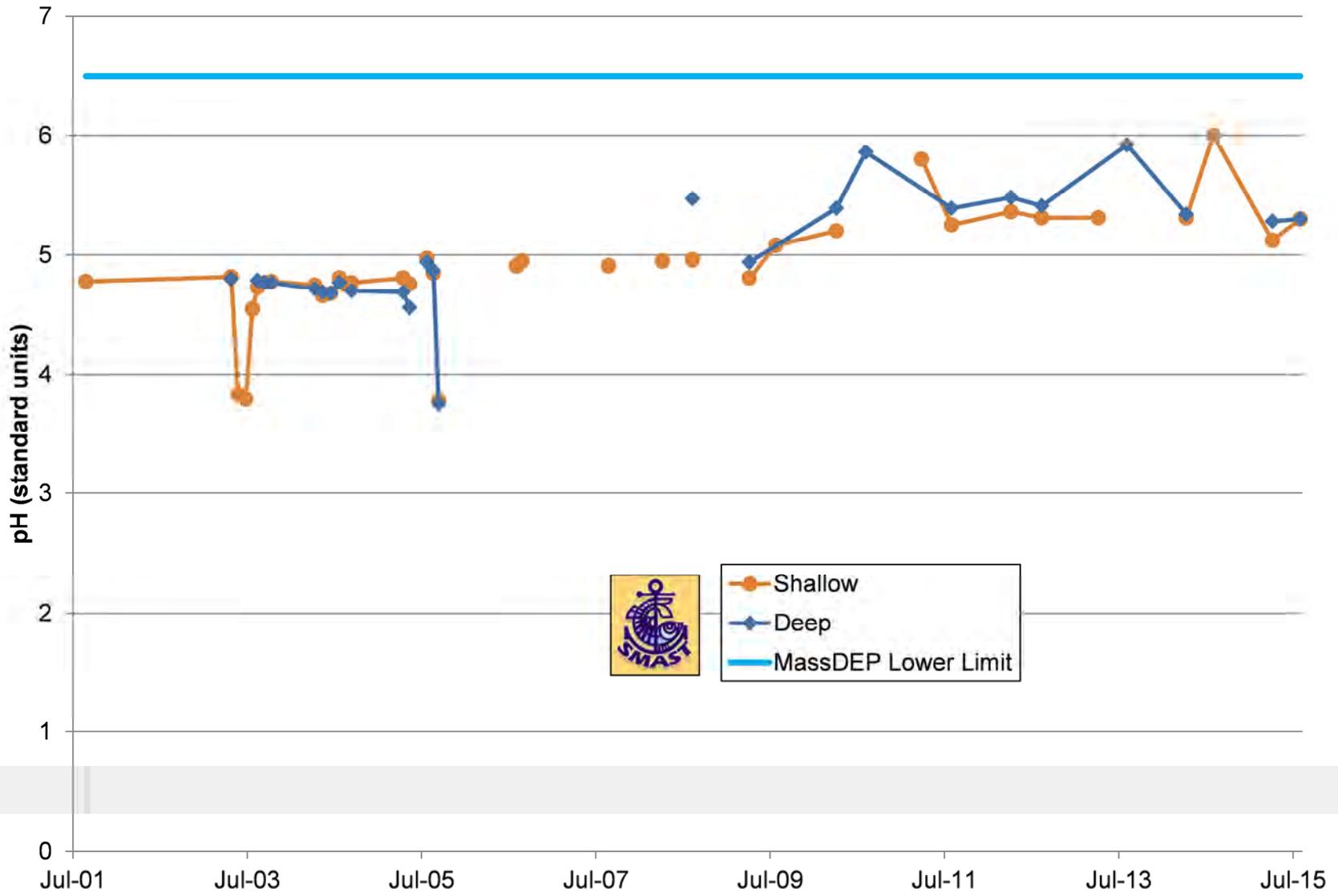
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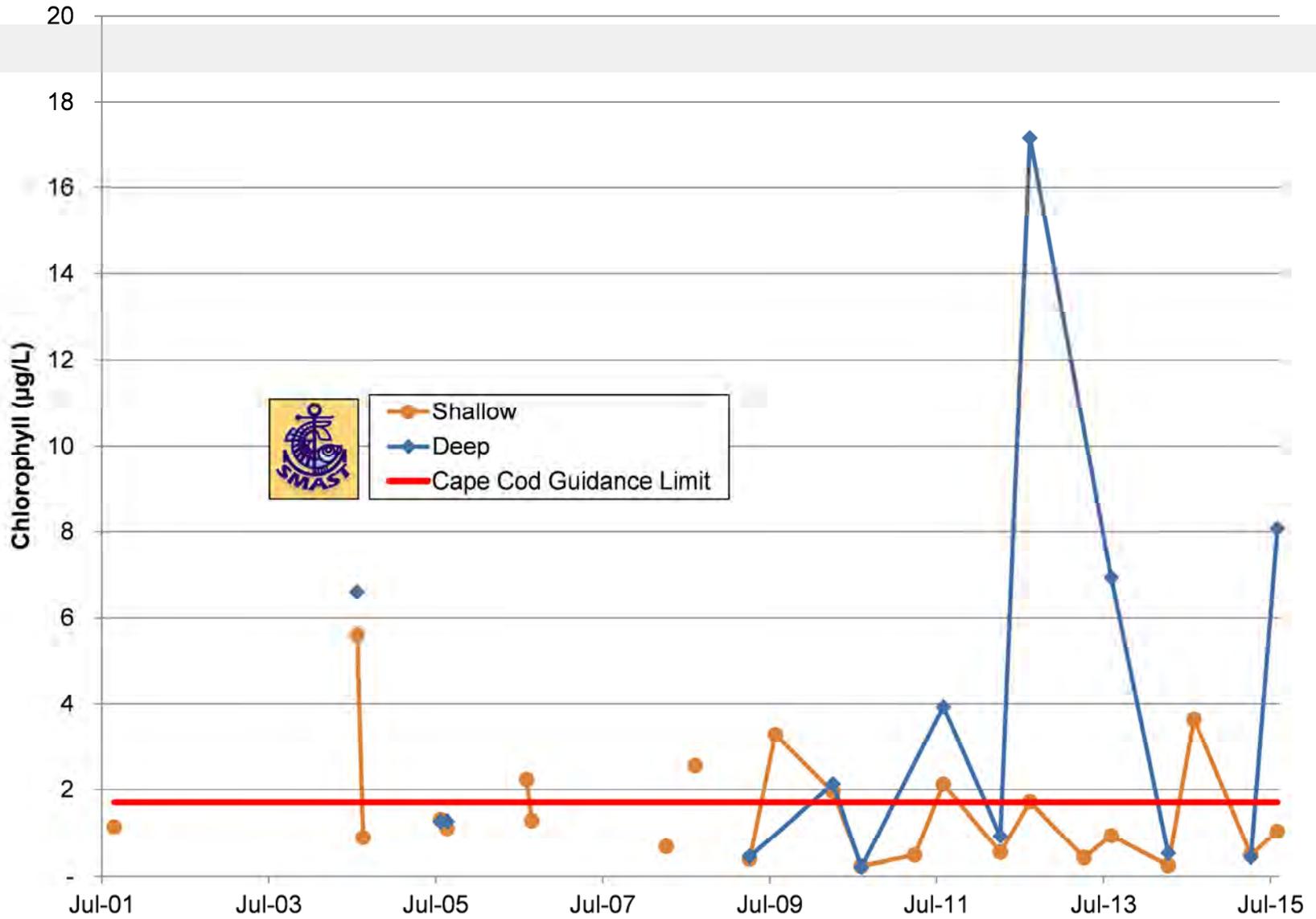
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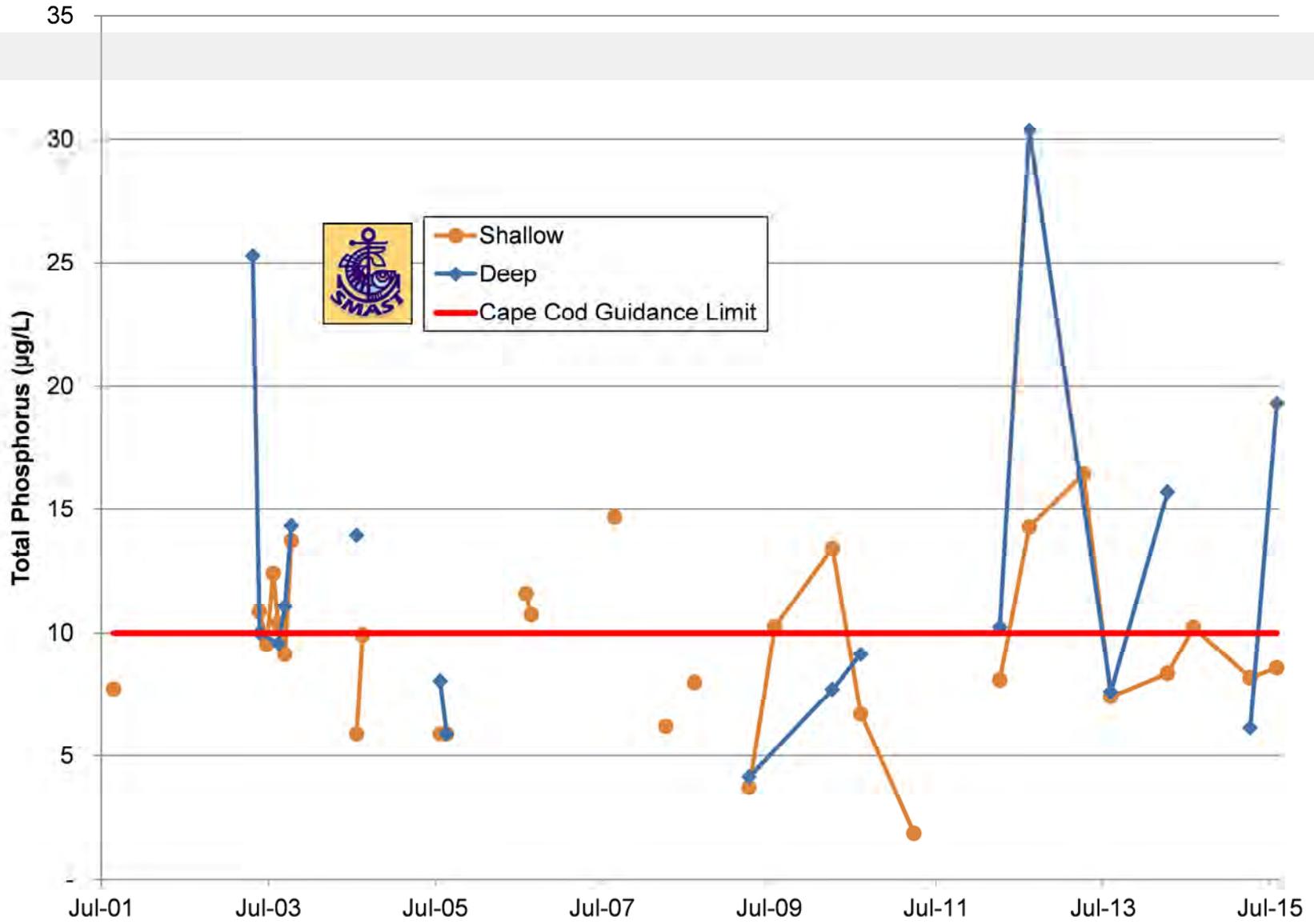
Flax Pond: Dennis



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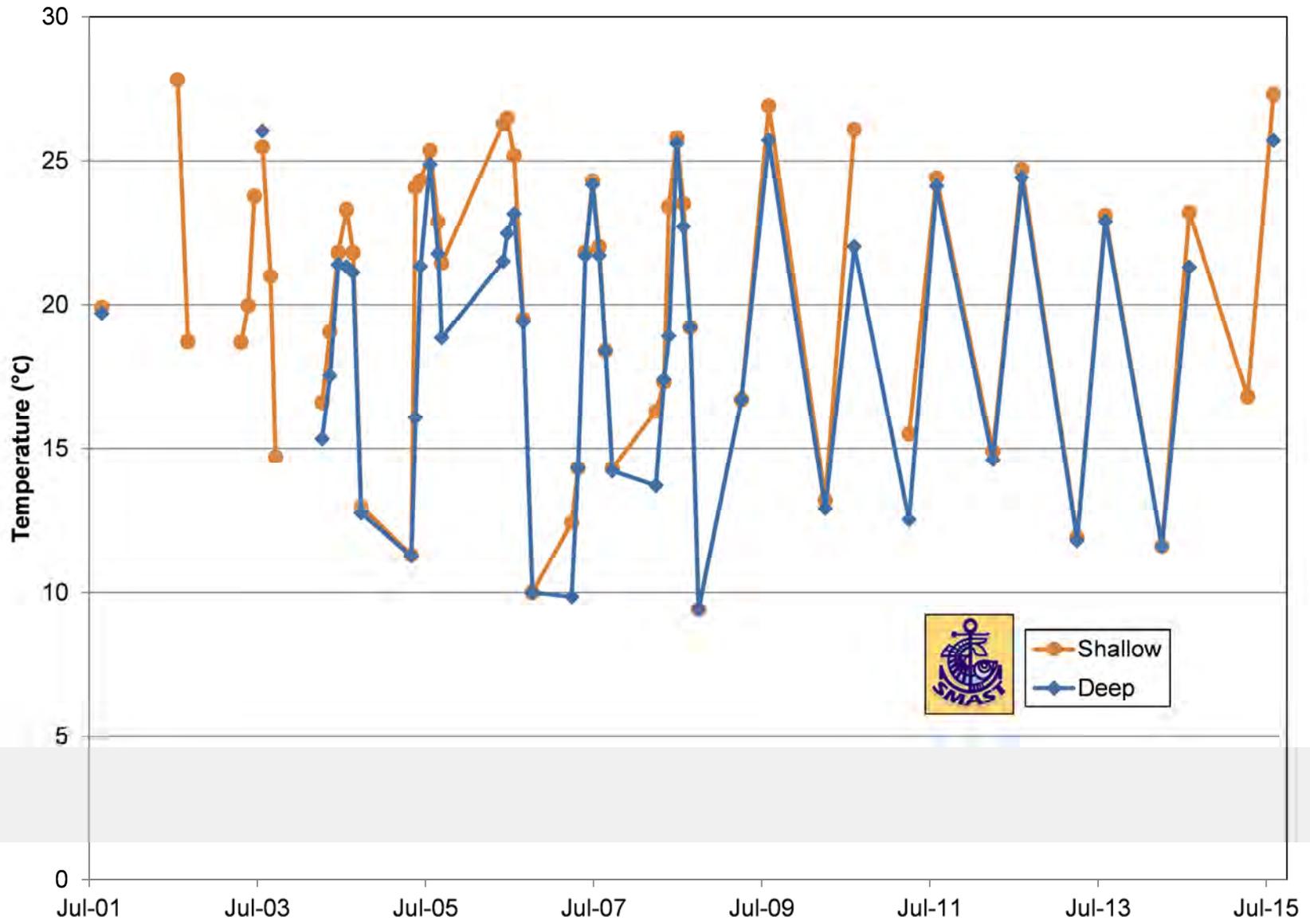


Flax Pond: Dennis

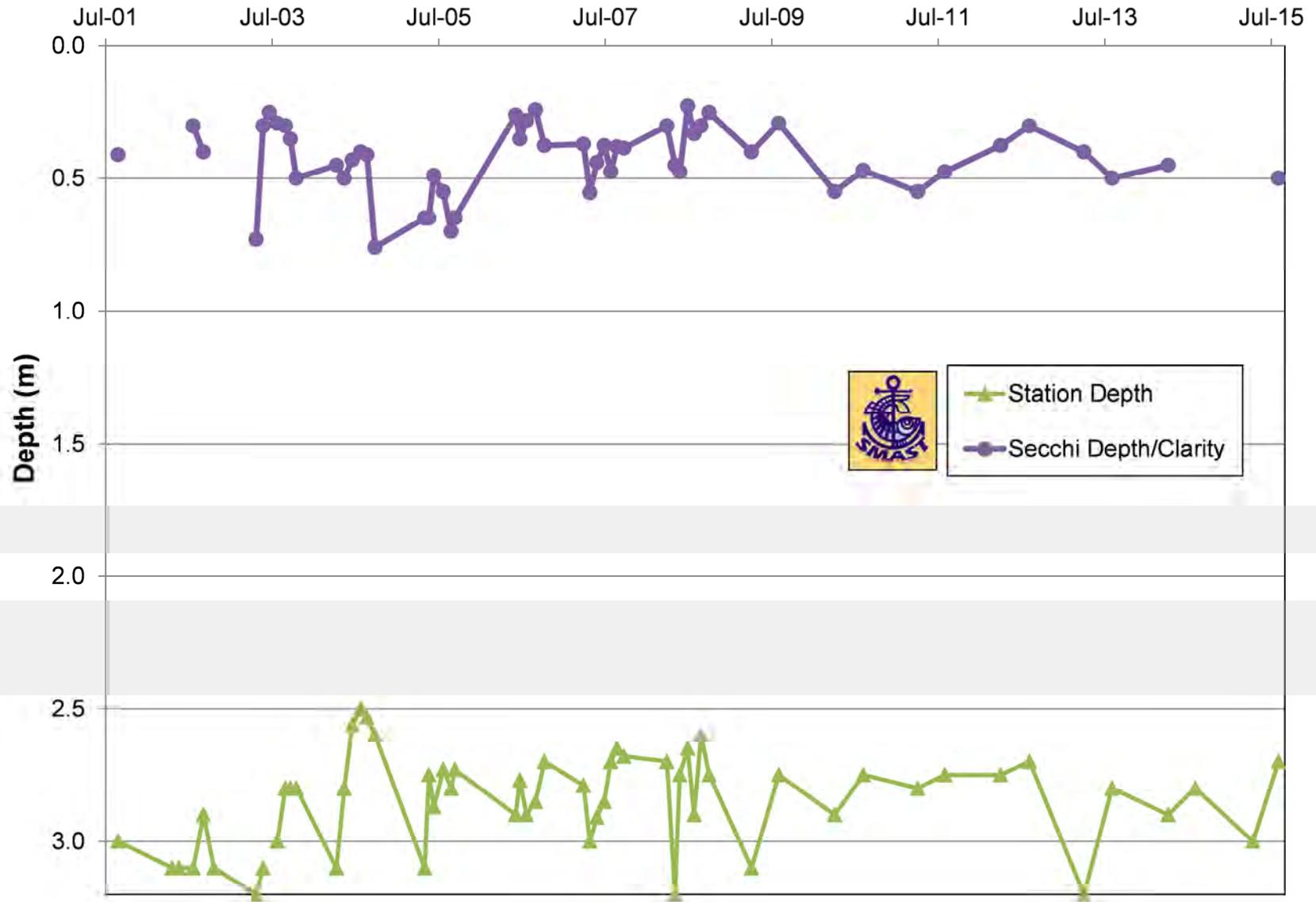


Fresh Pond

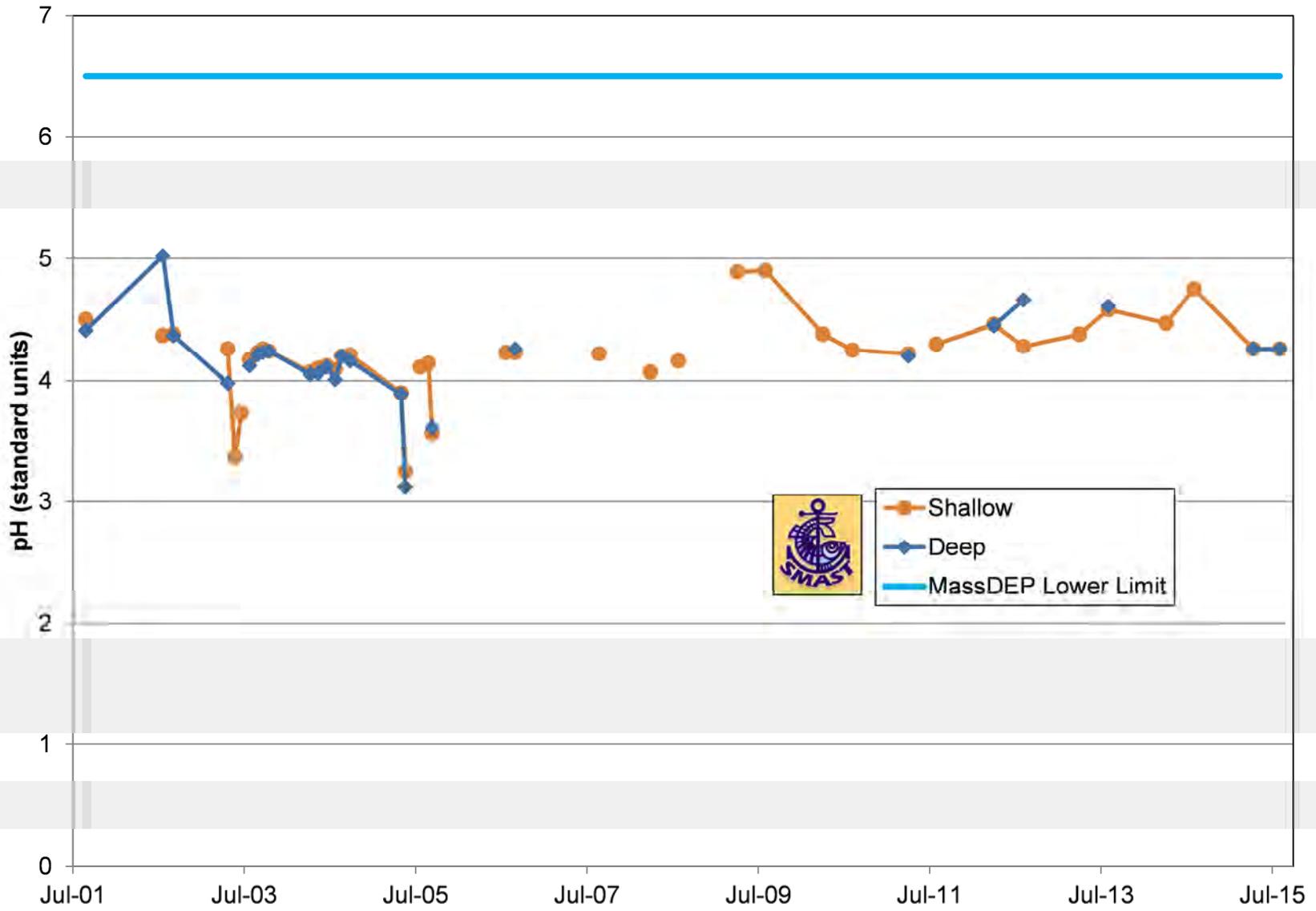
Fresh Pond: Dennis



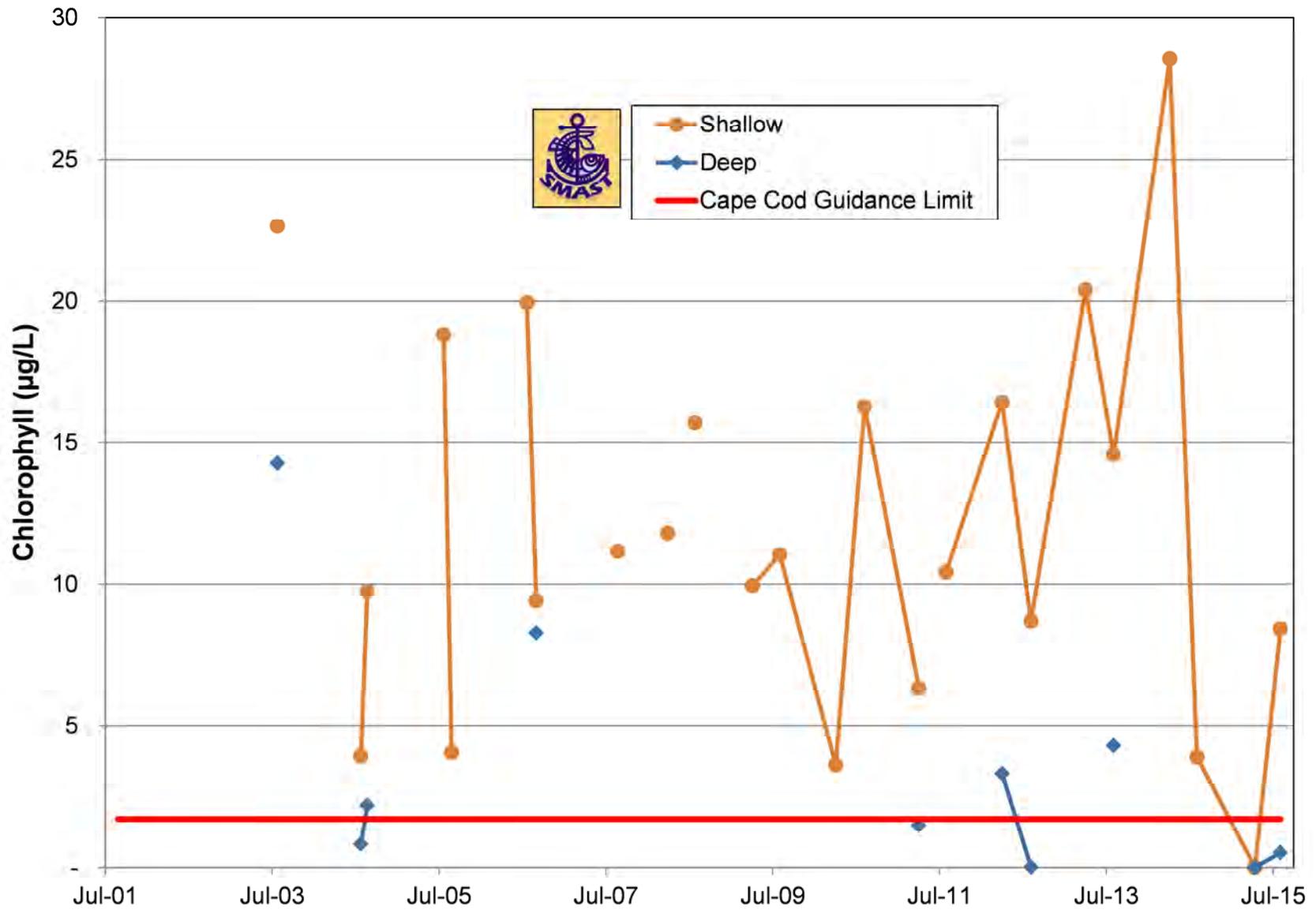
Fresh Pond: Dennis



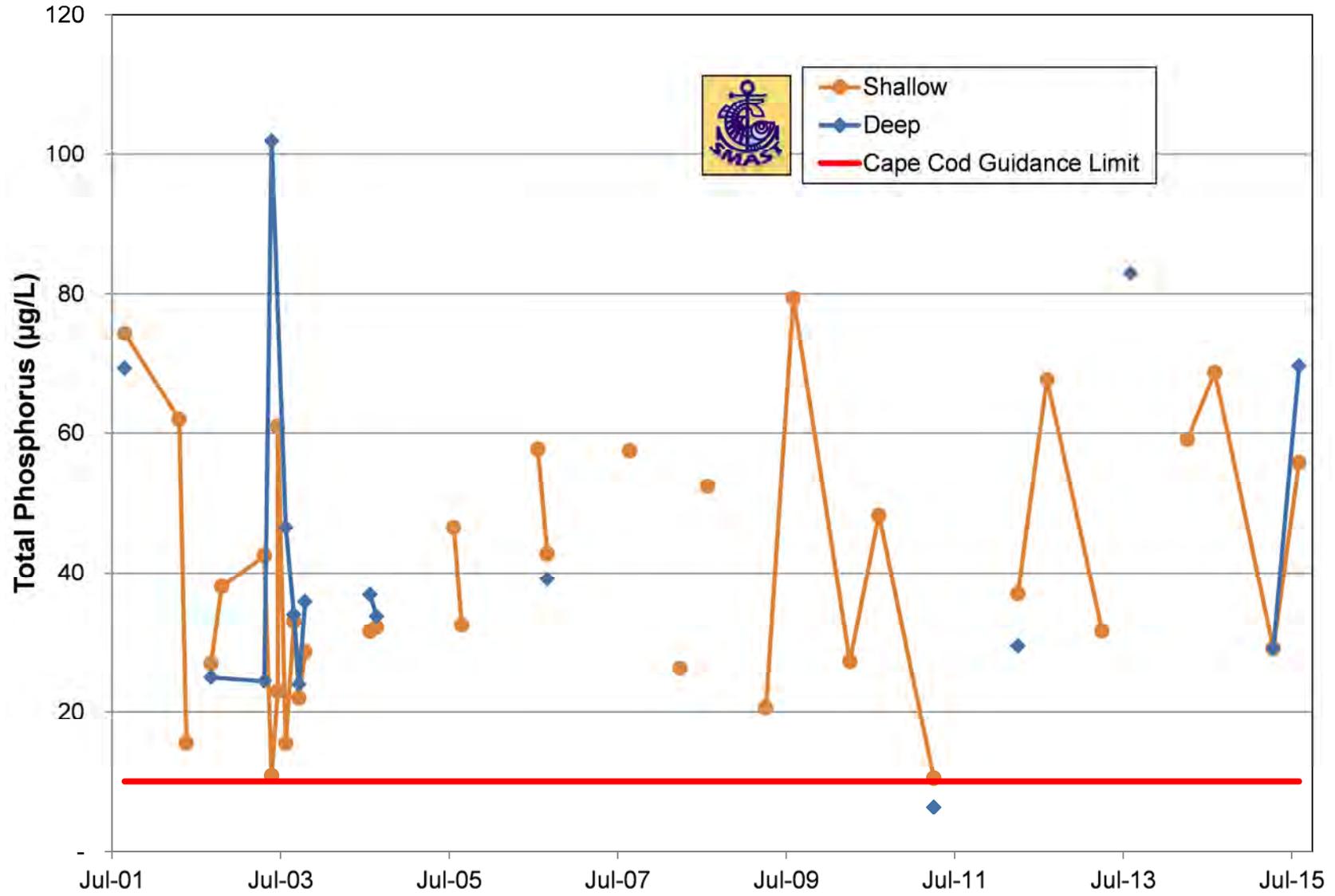
Fresh Pond: Dennis



Fresh Pond: Dennis

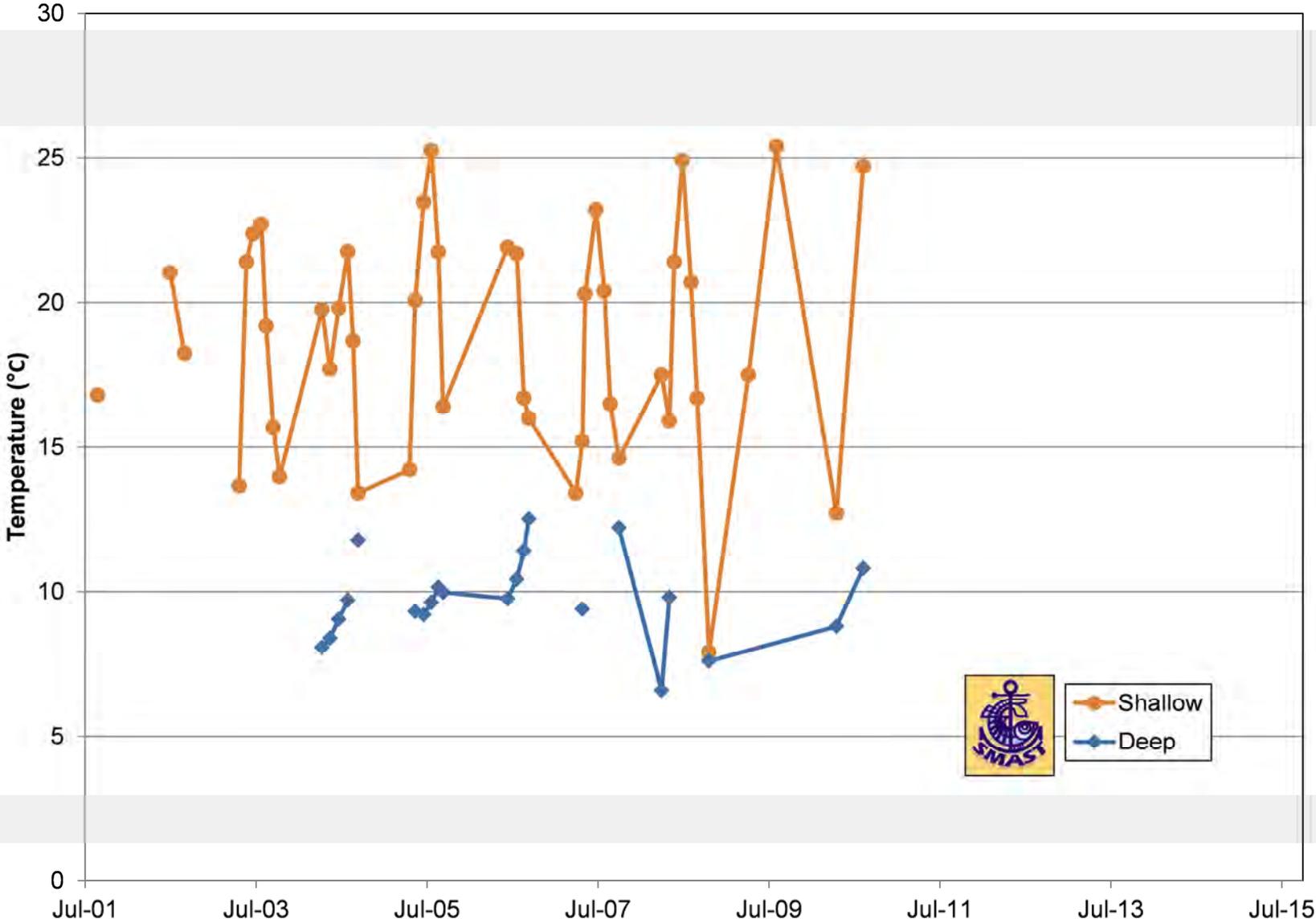


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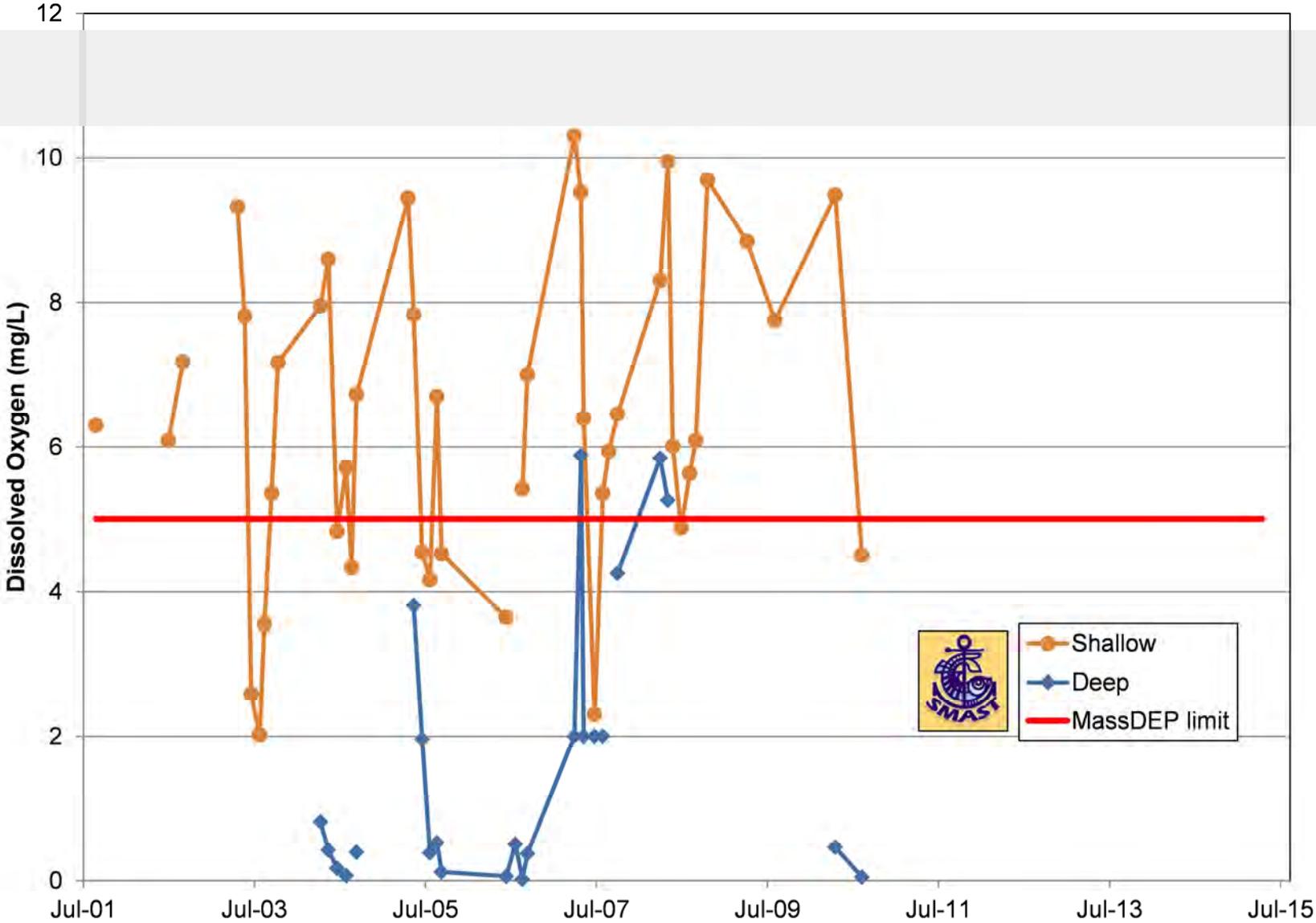


Hiram Pond

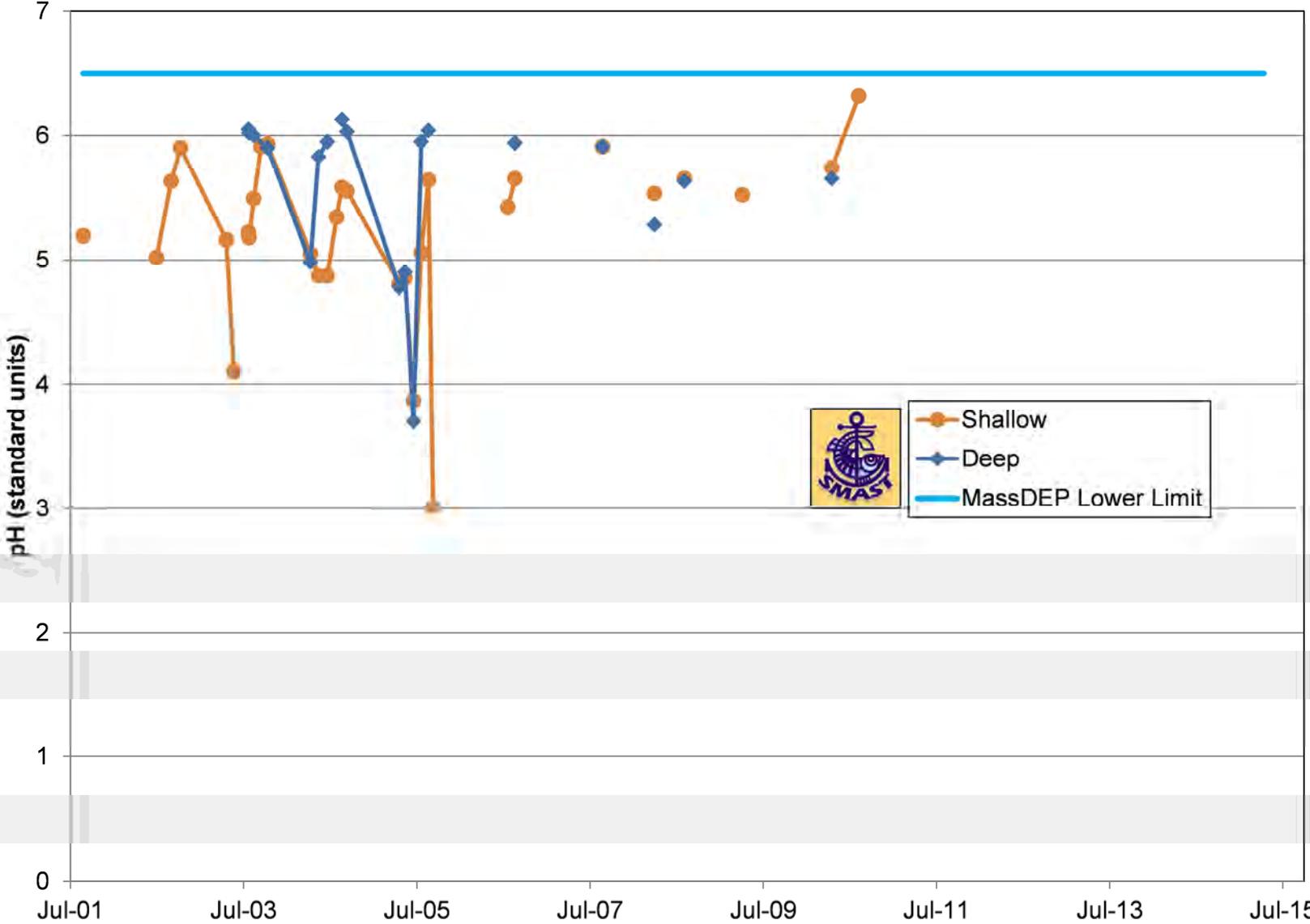
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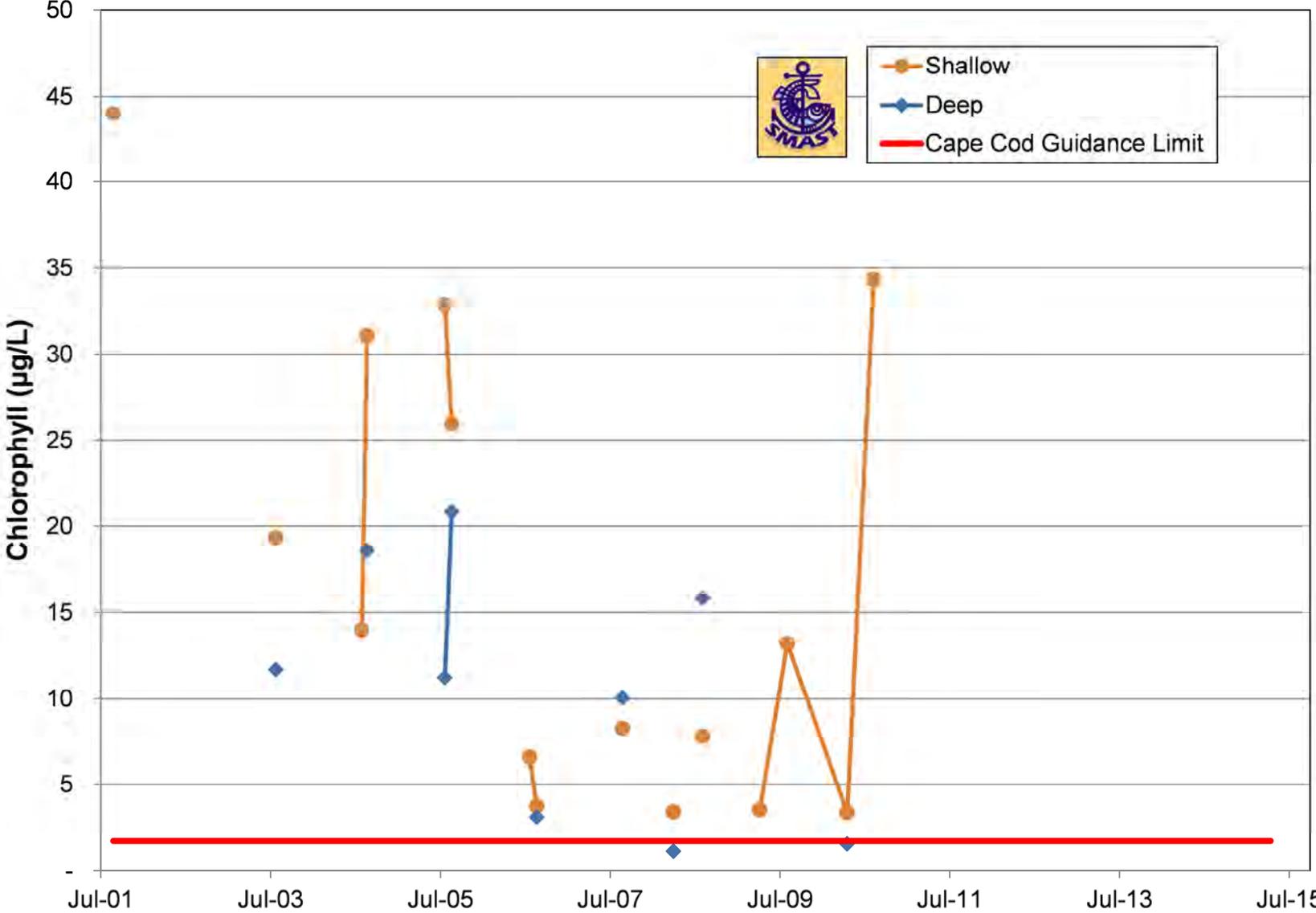
Hiram Pond: Dennis



Hiram Pond: Dennis

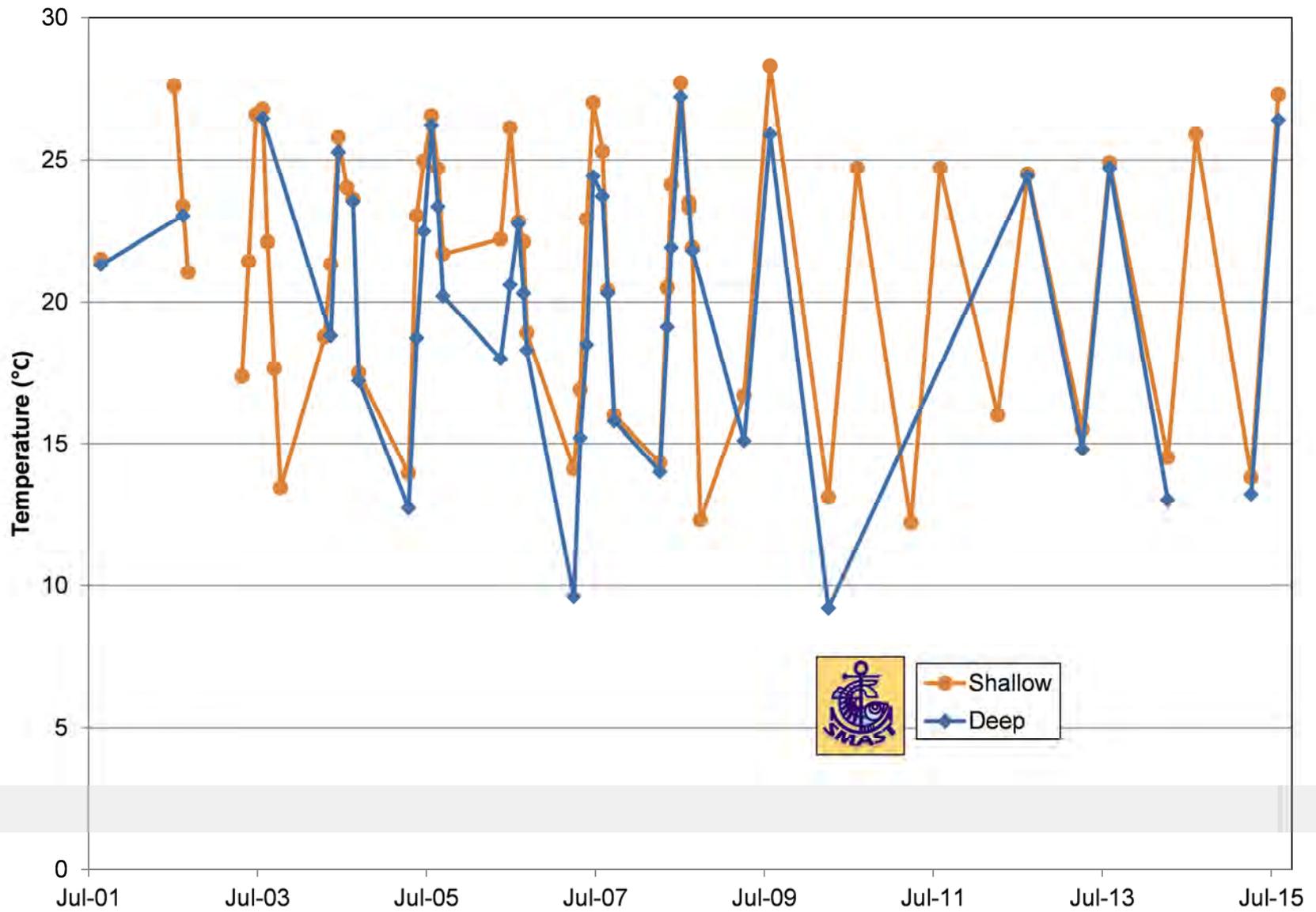


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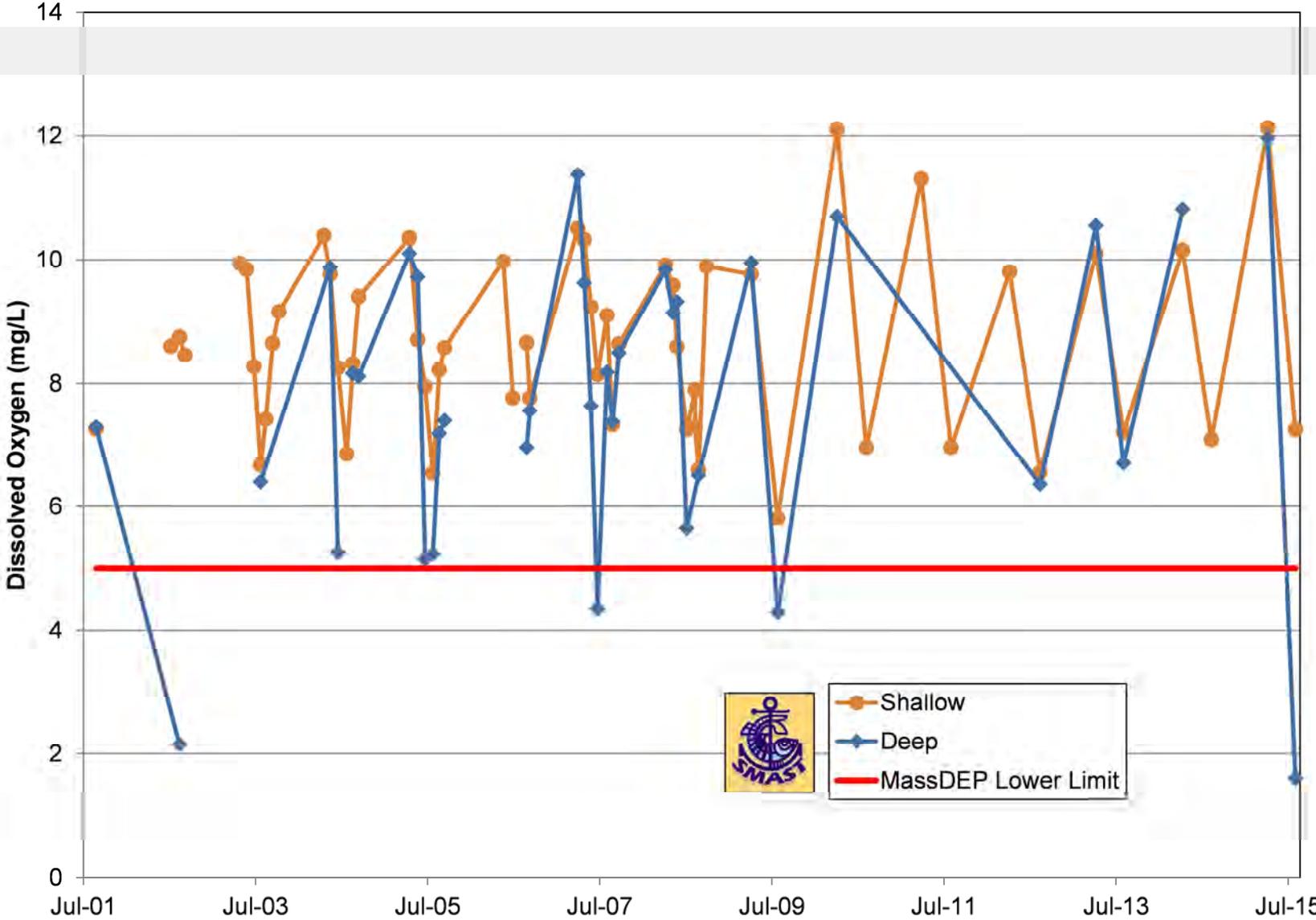


North Simmons Pond

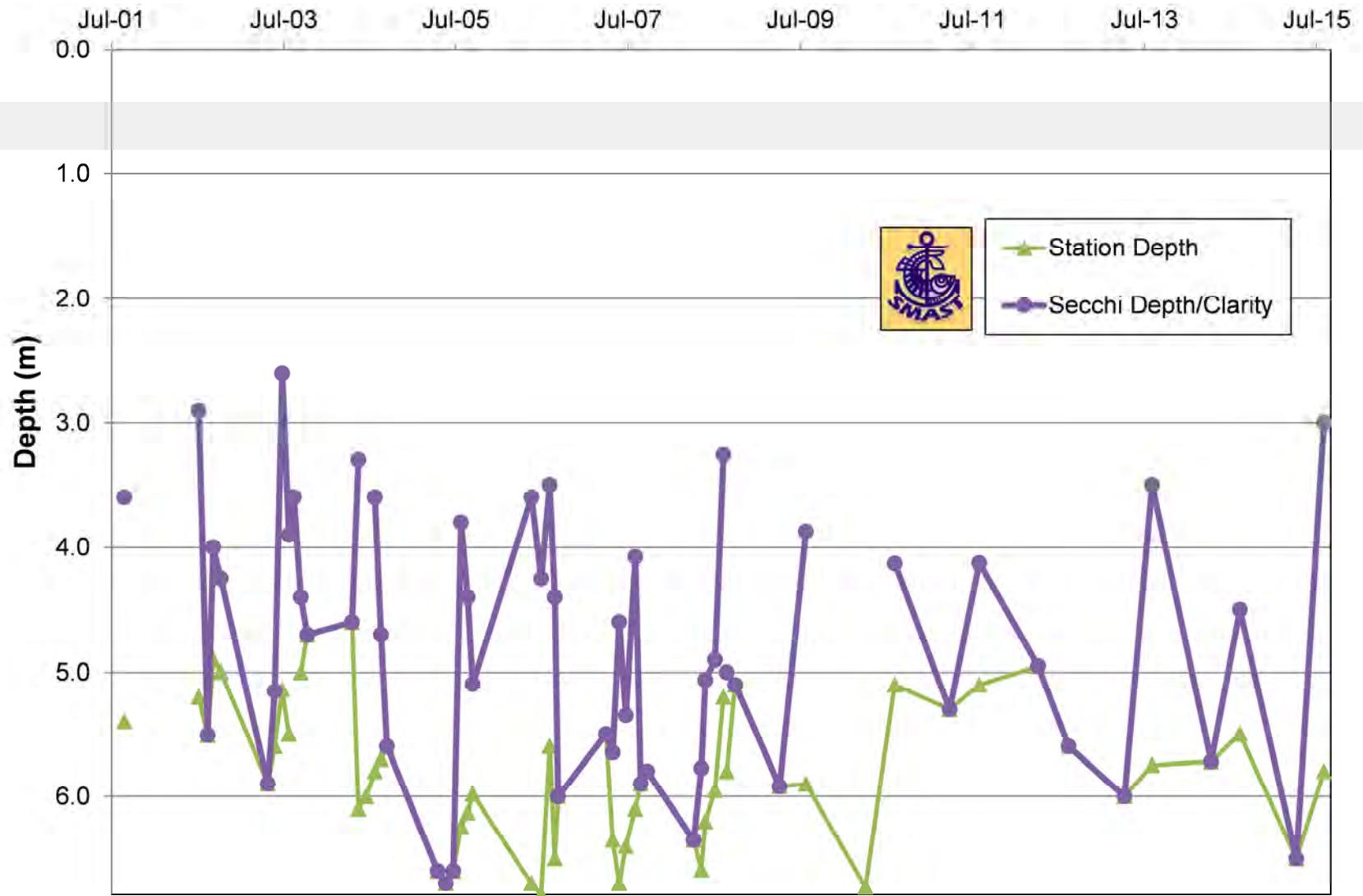
North Simmons Pond: Dennis



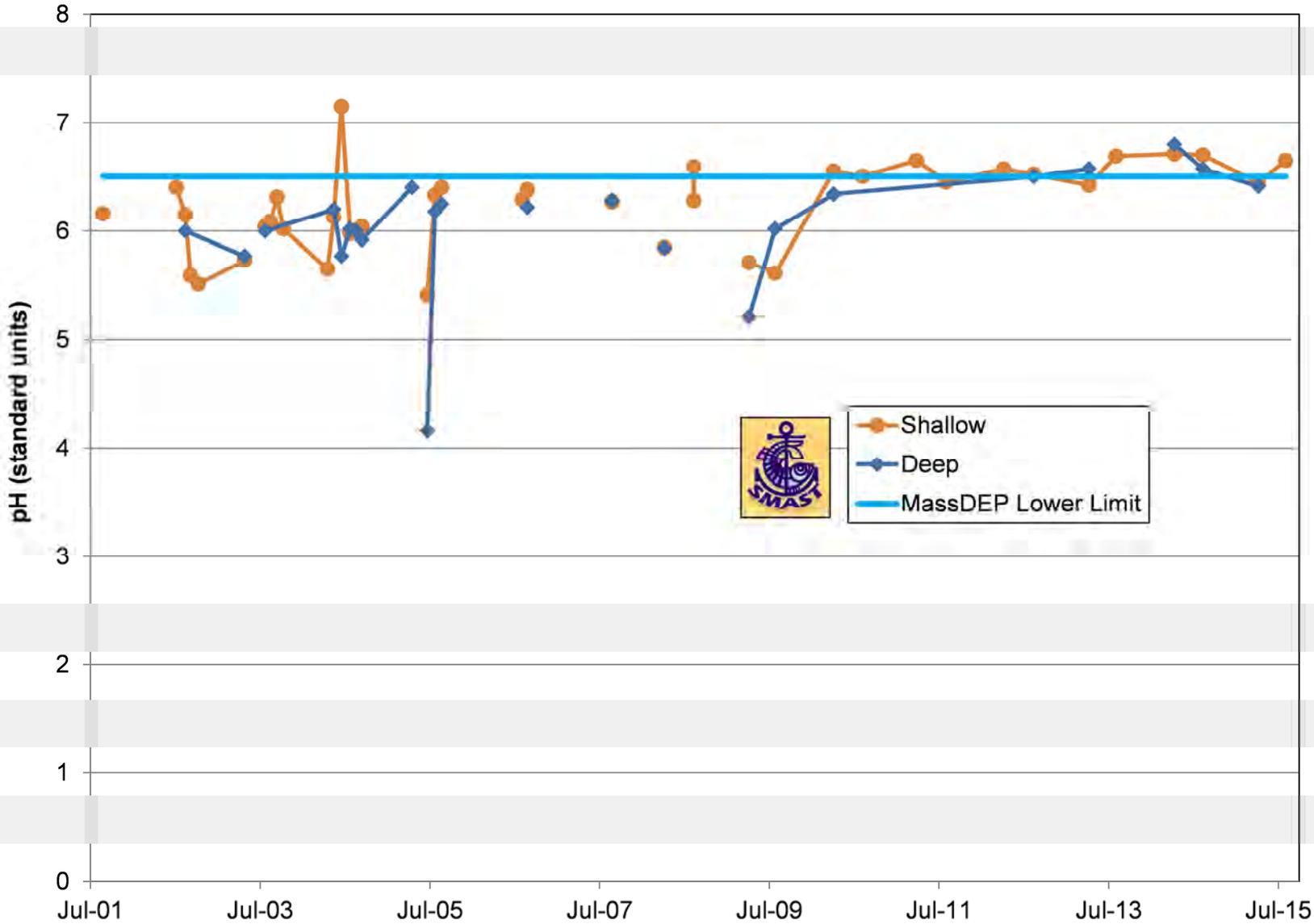
North Simmons Pond: Dennis



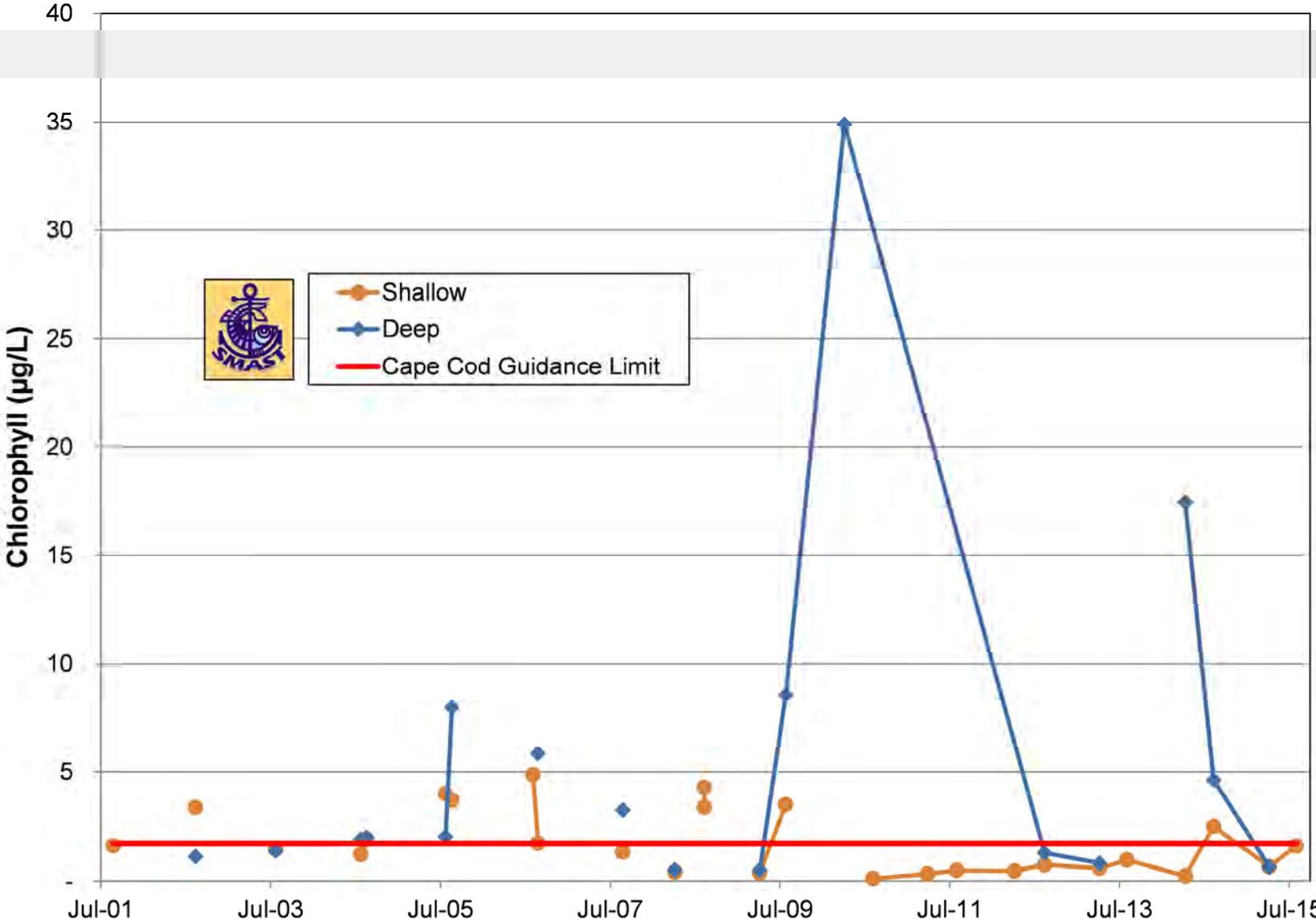
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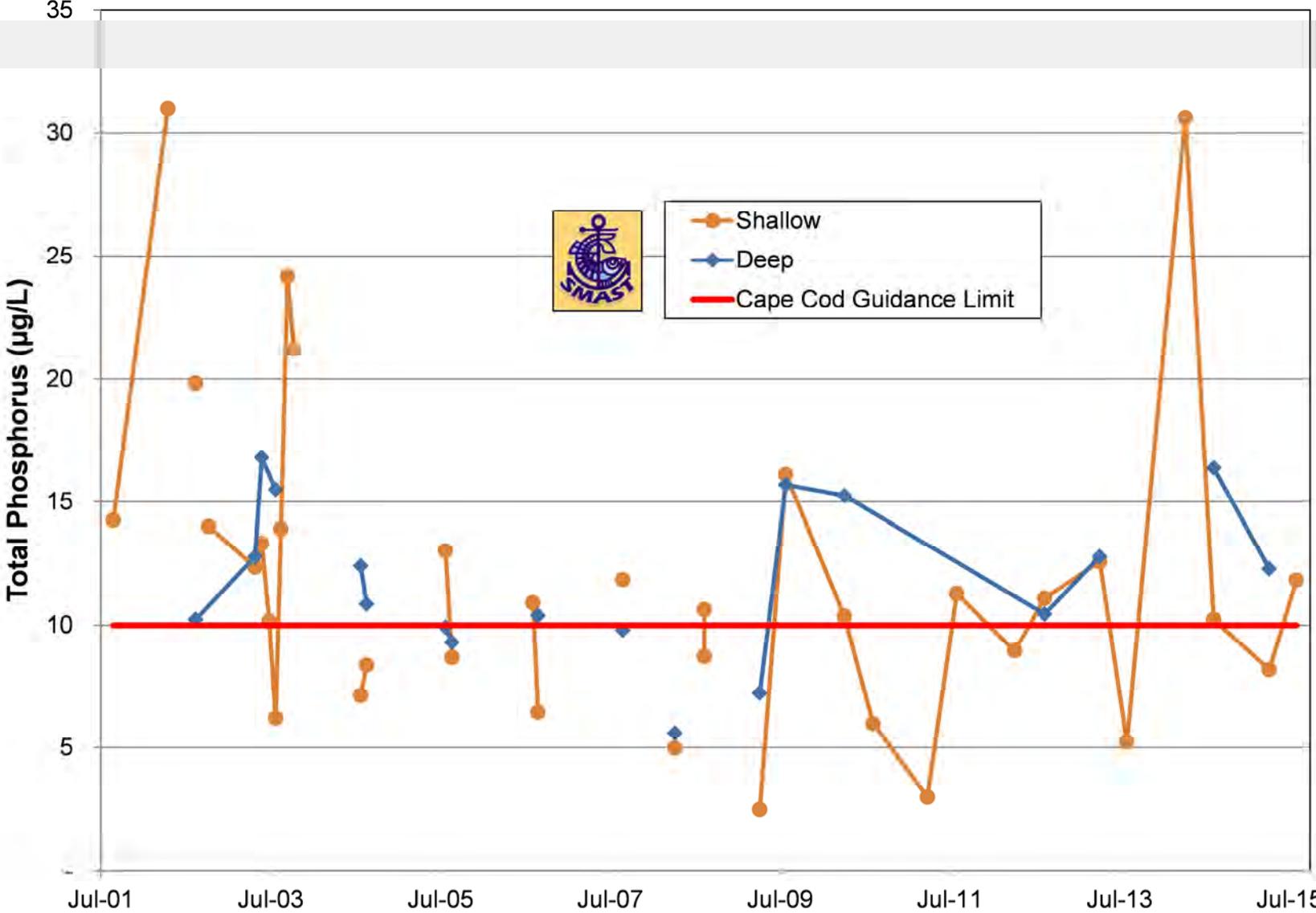
North Simmons Pond: Dennis



North Simmons Pond: Dennis

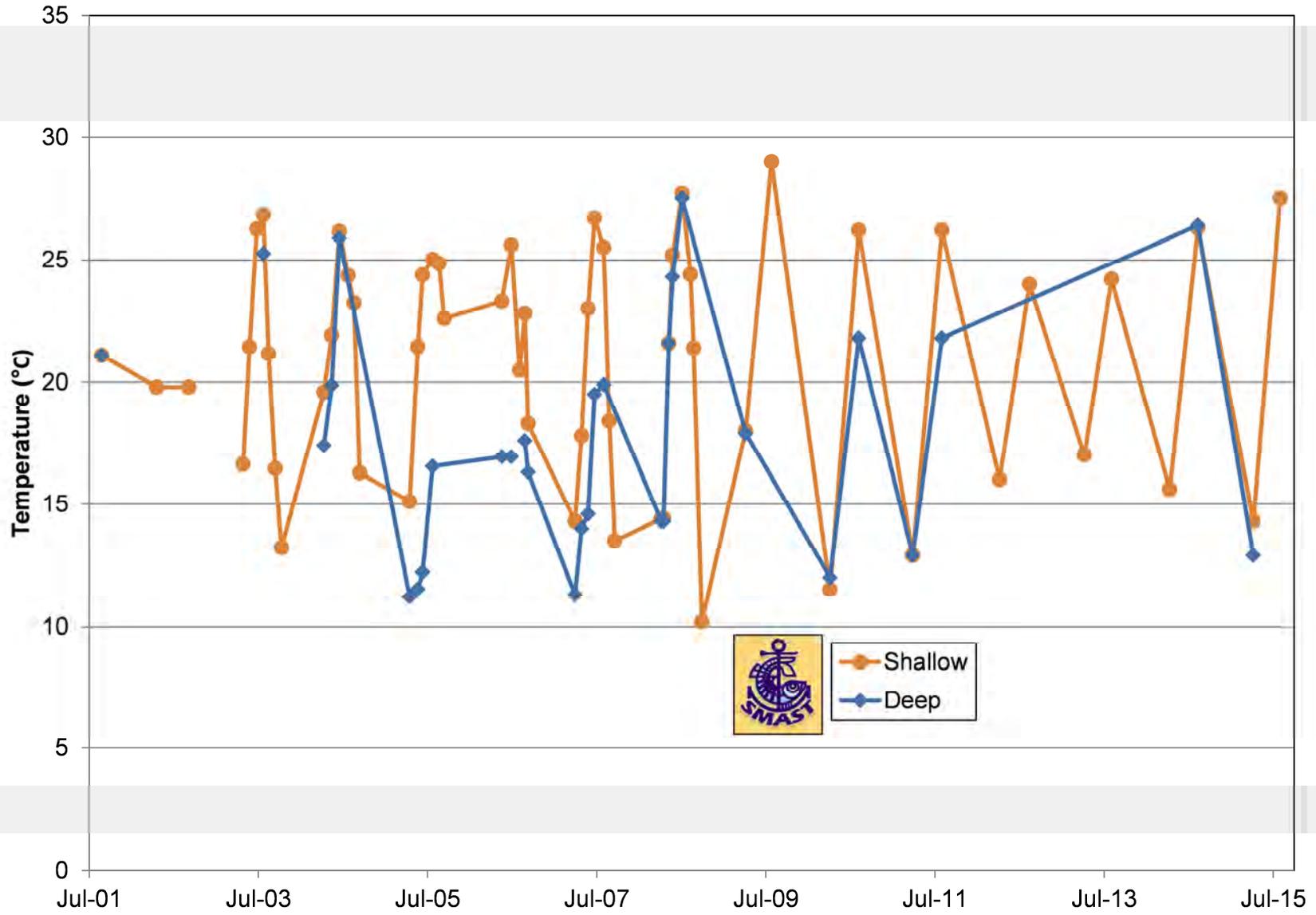


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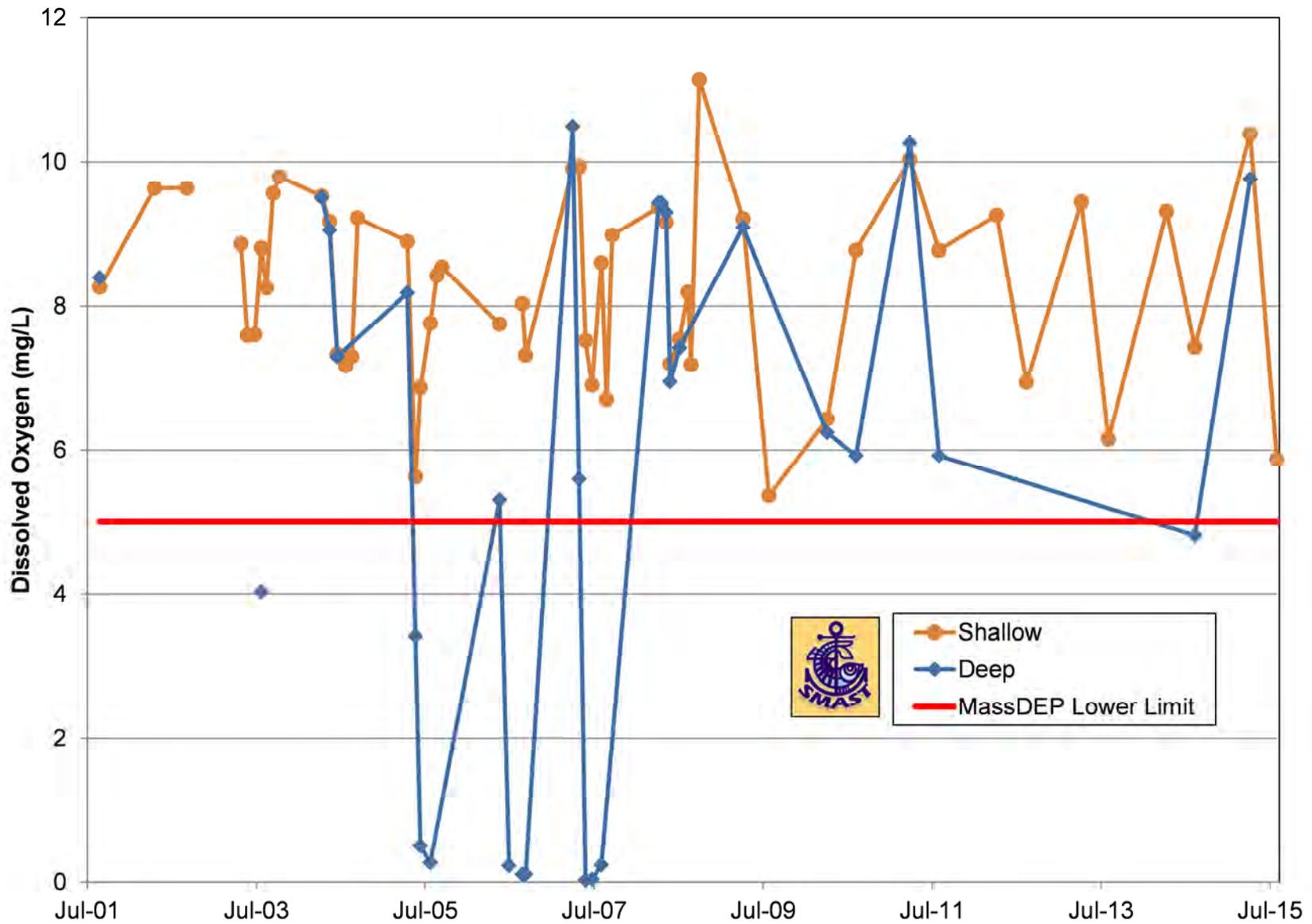


Run Pond

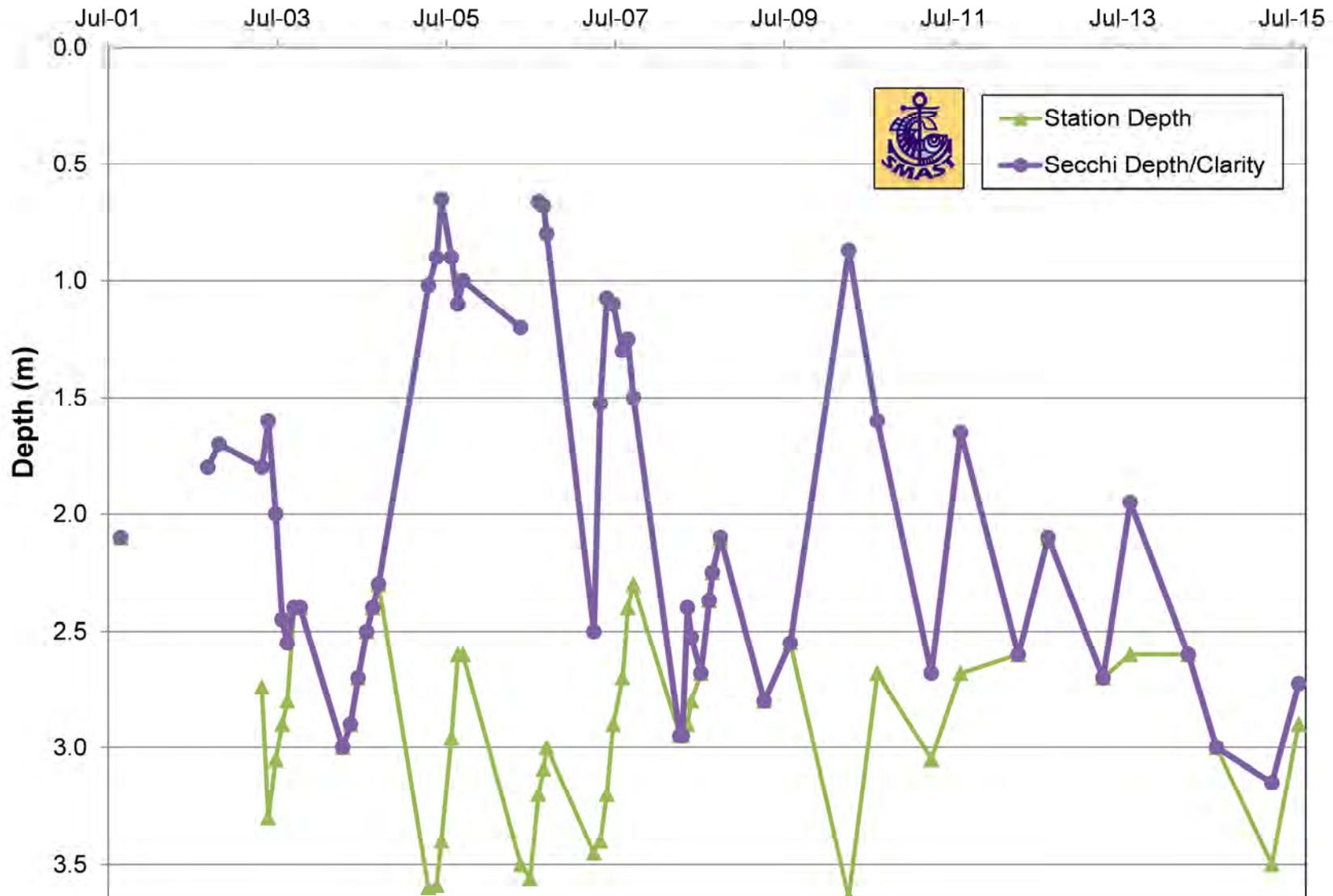
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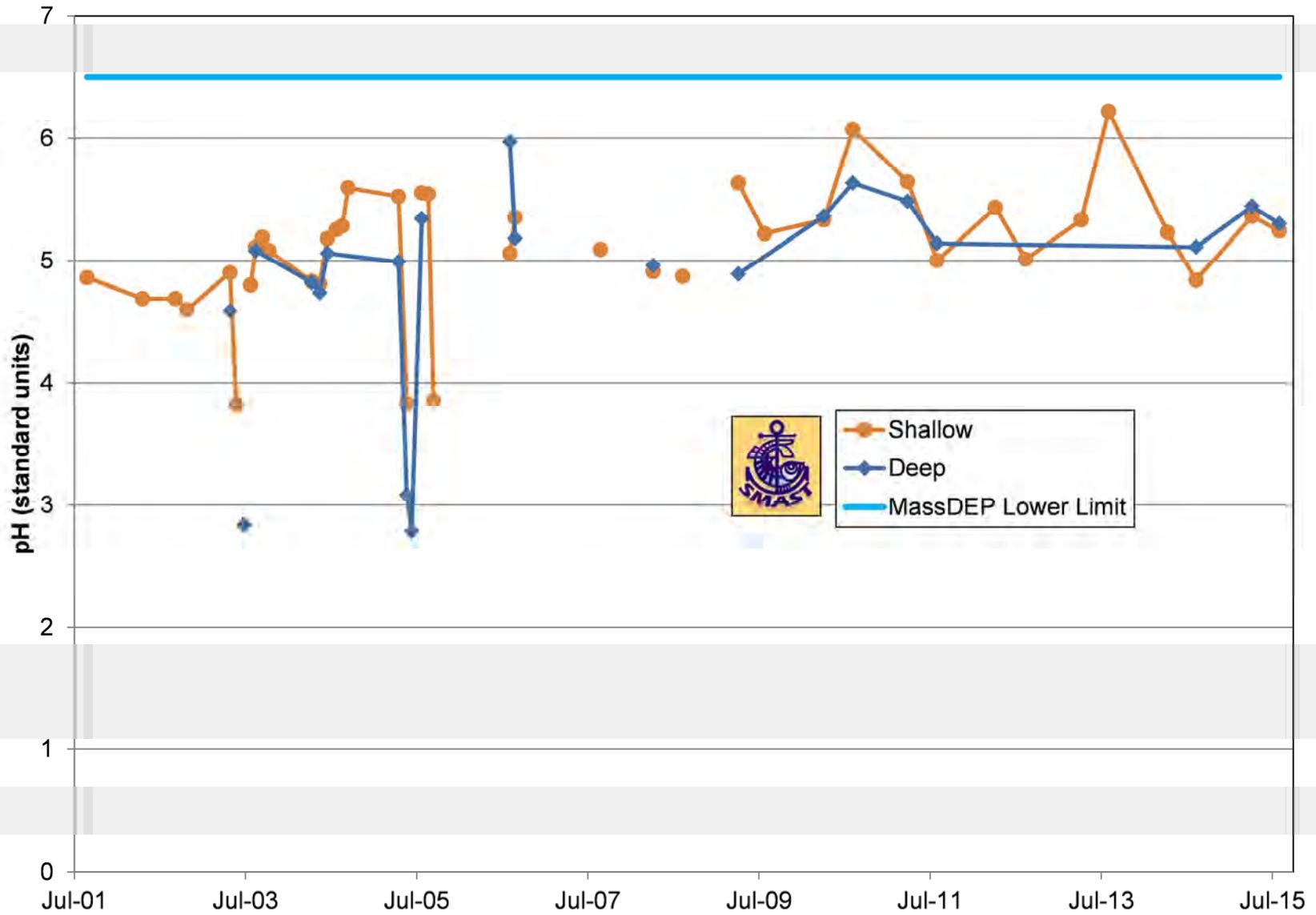
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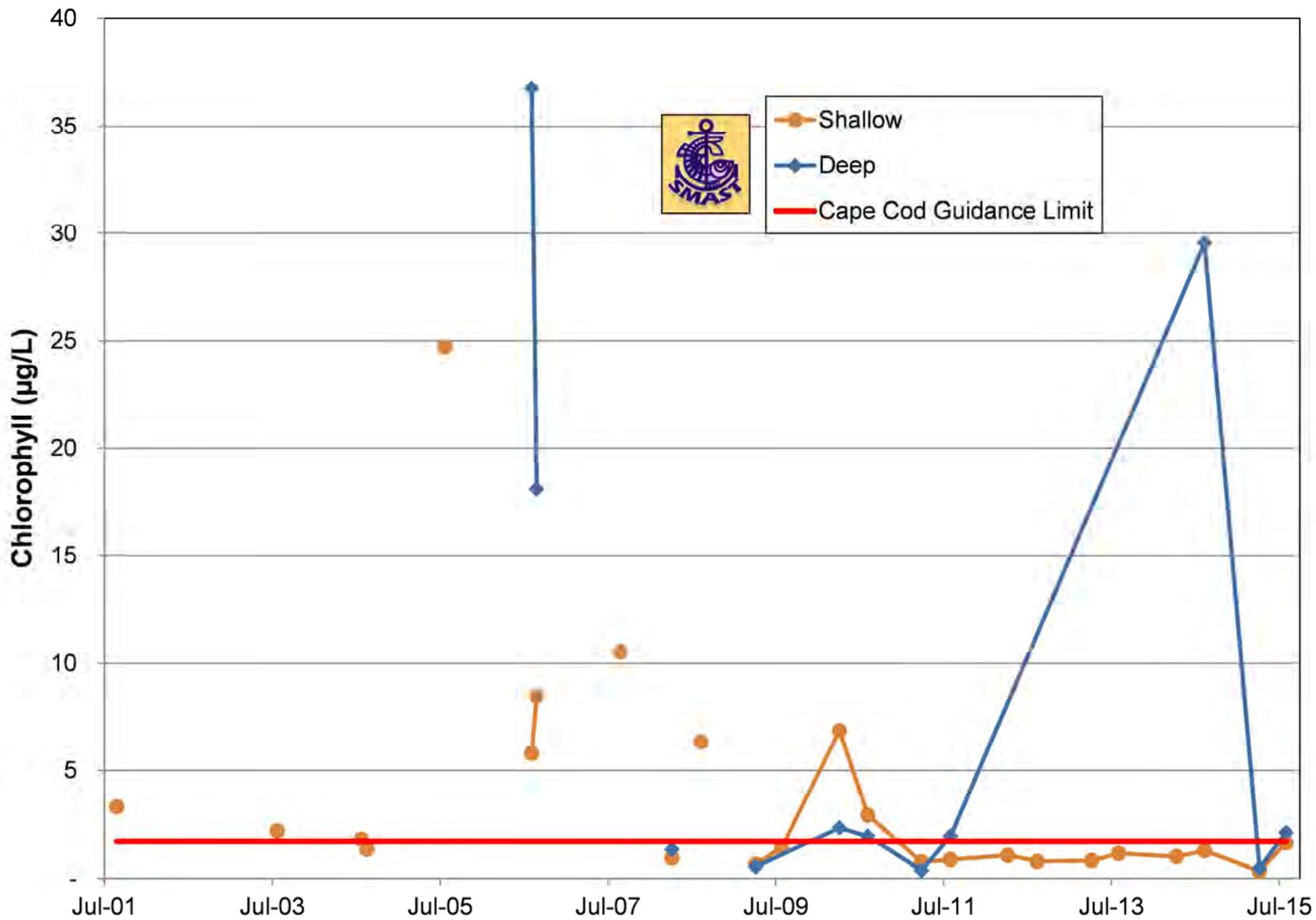
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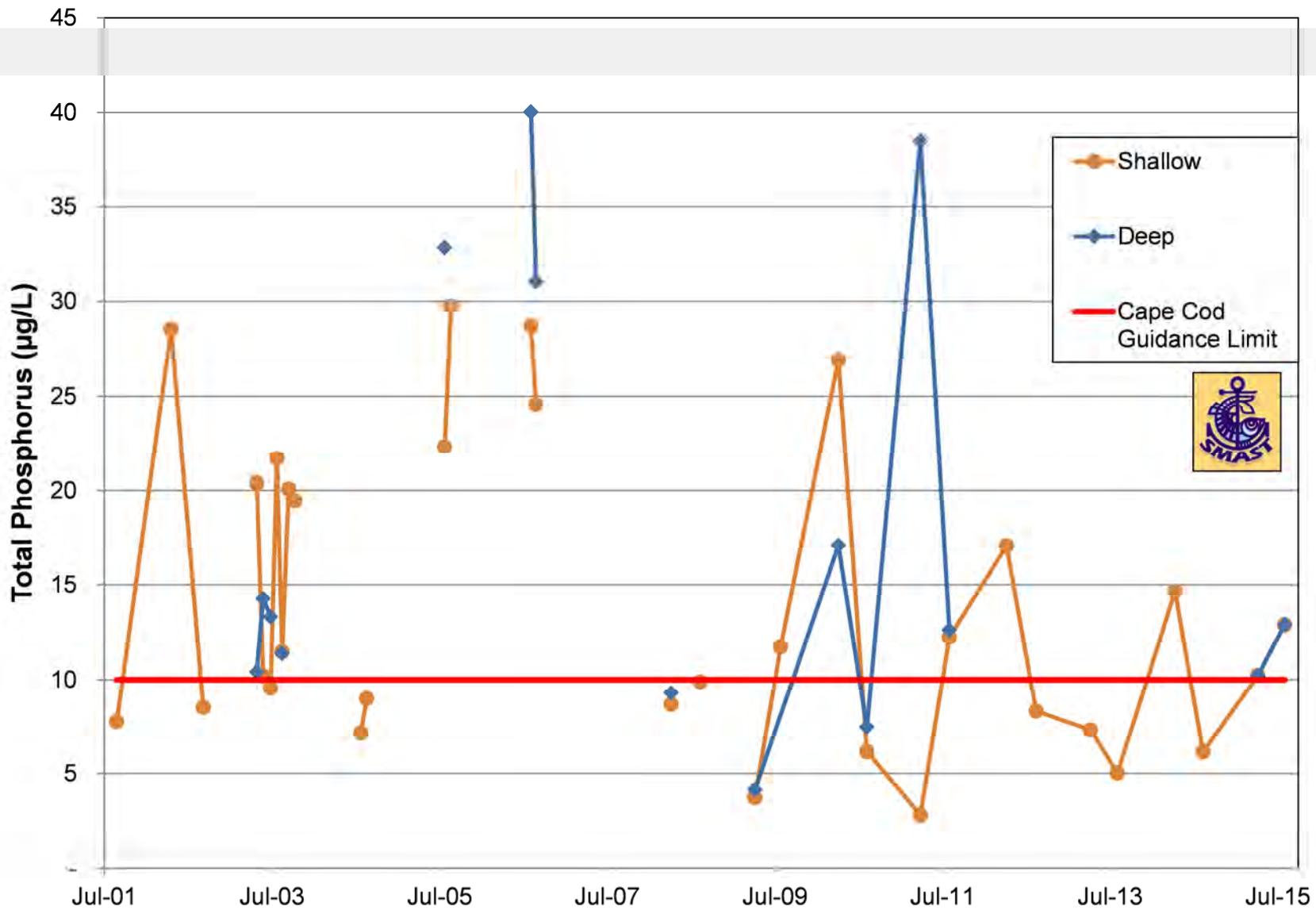
Run Pond: Dennis



Run Pond: Dennis

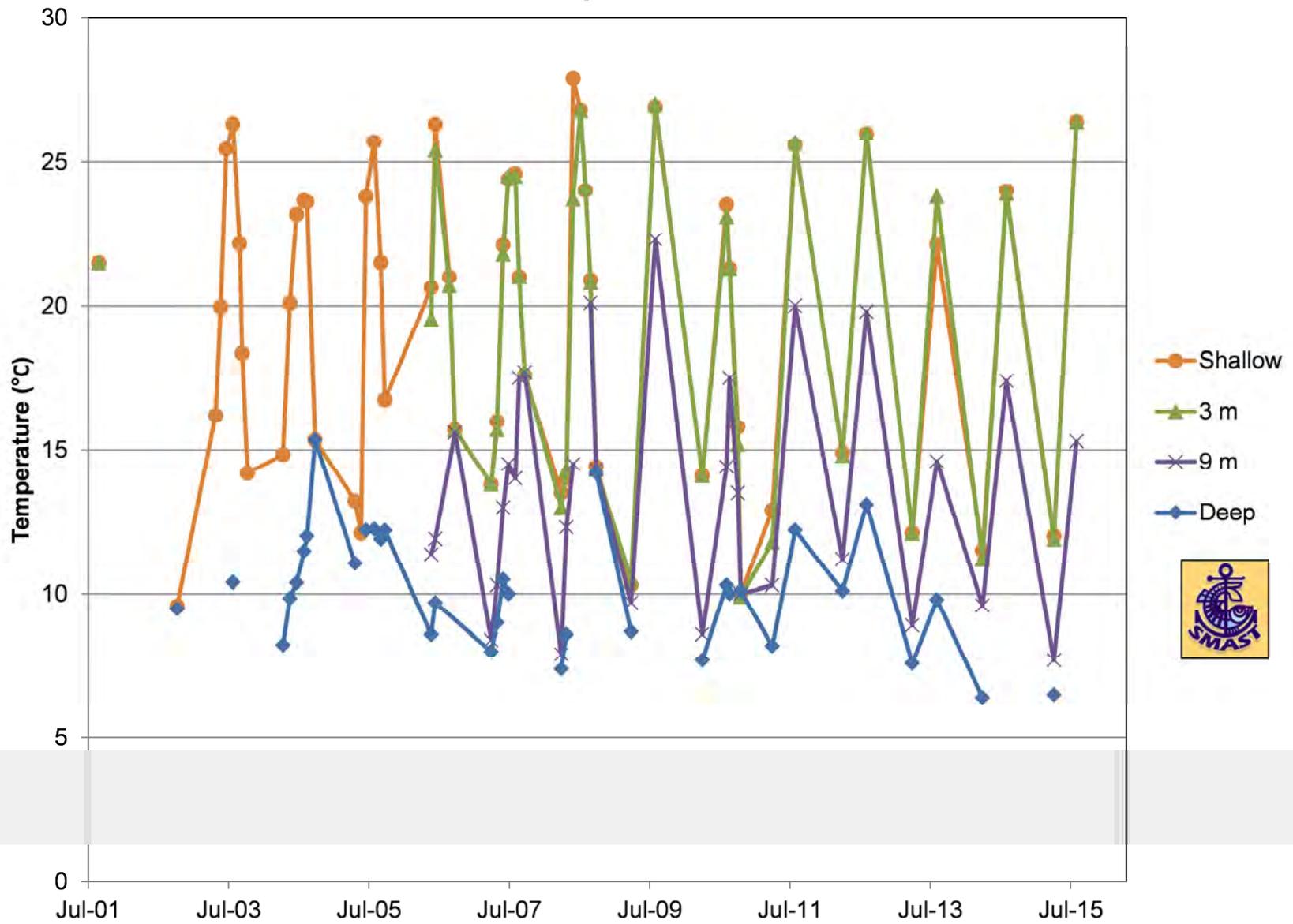


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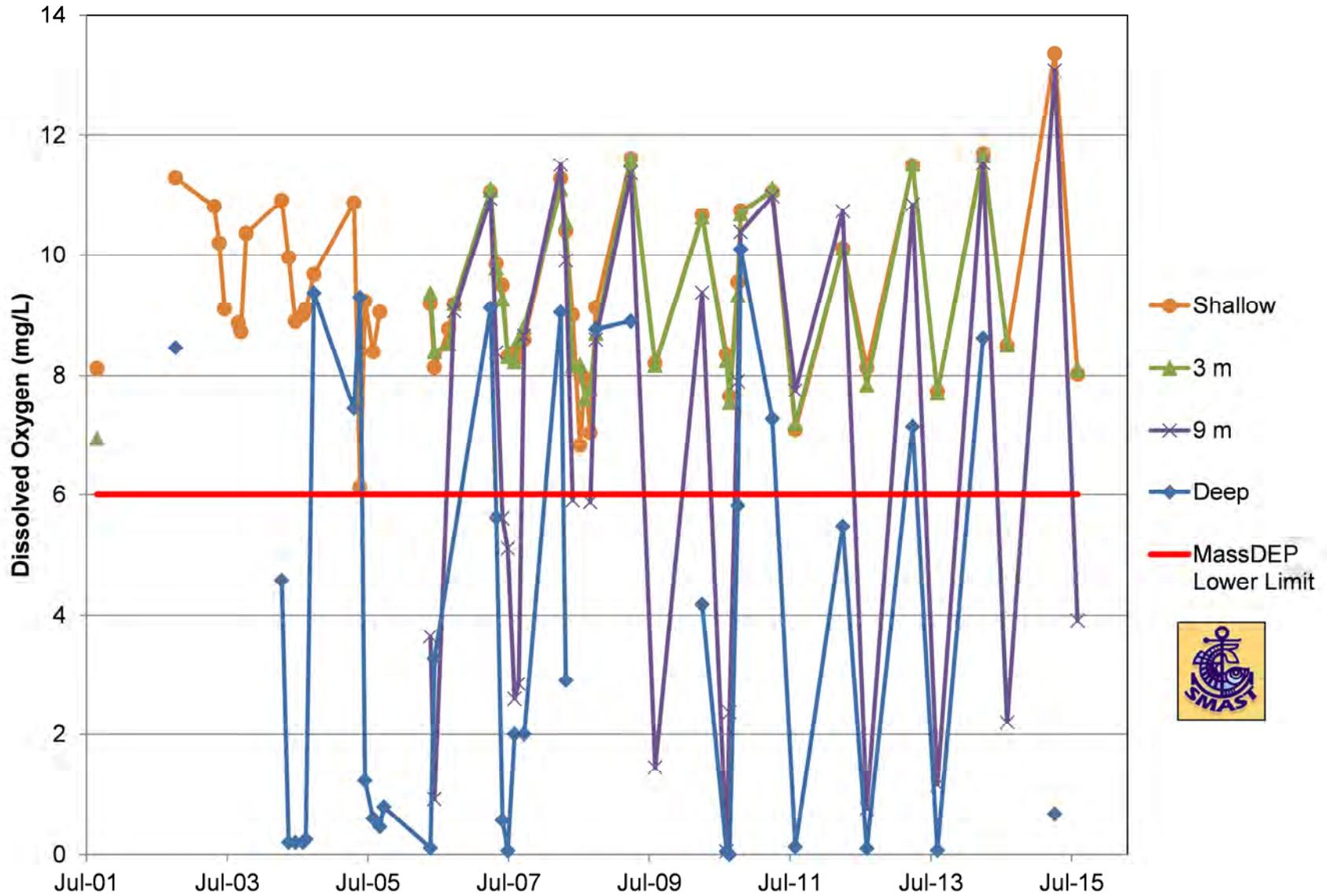


Scargo Lake

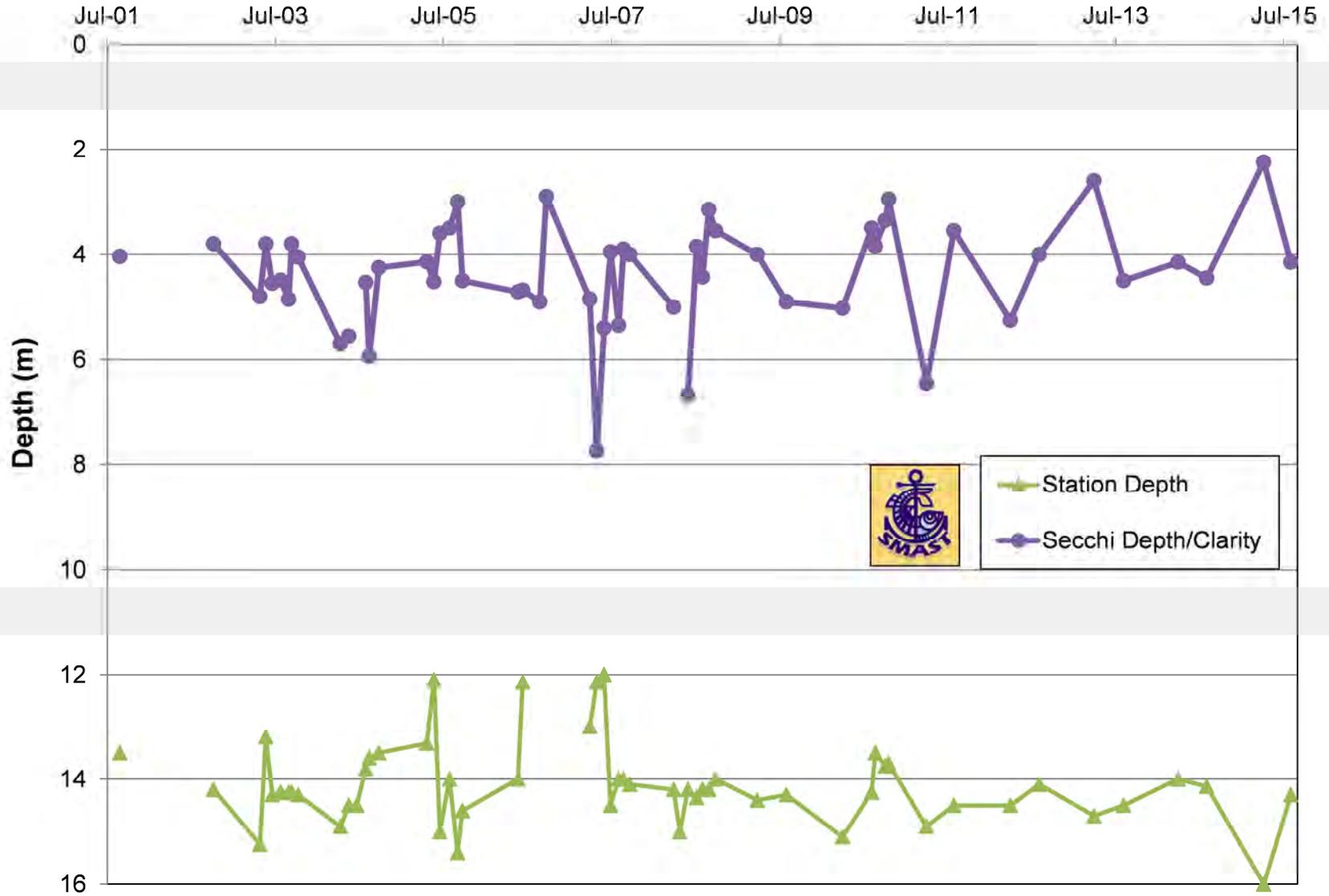
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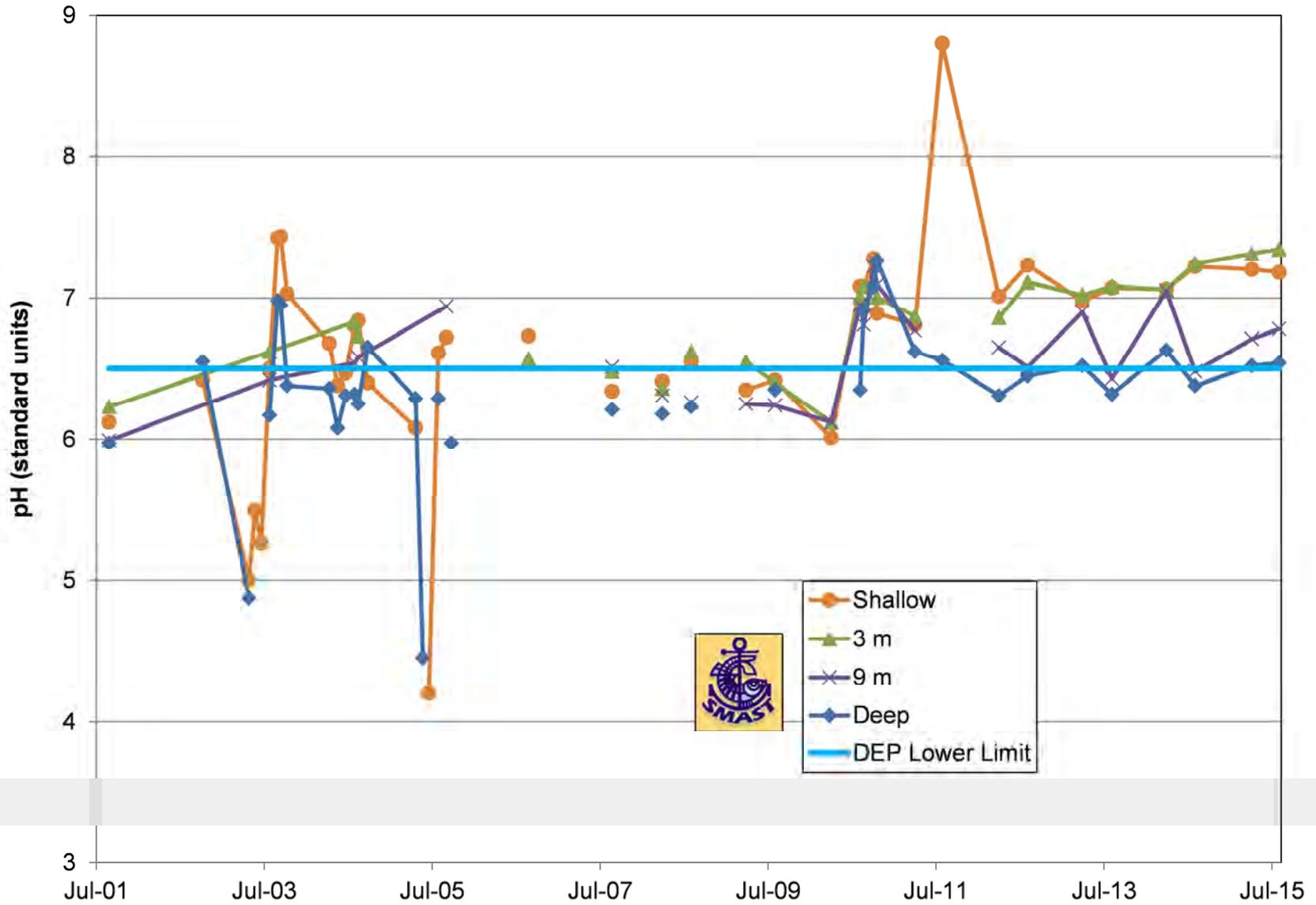
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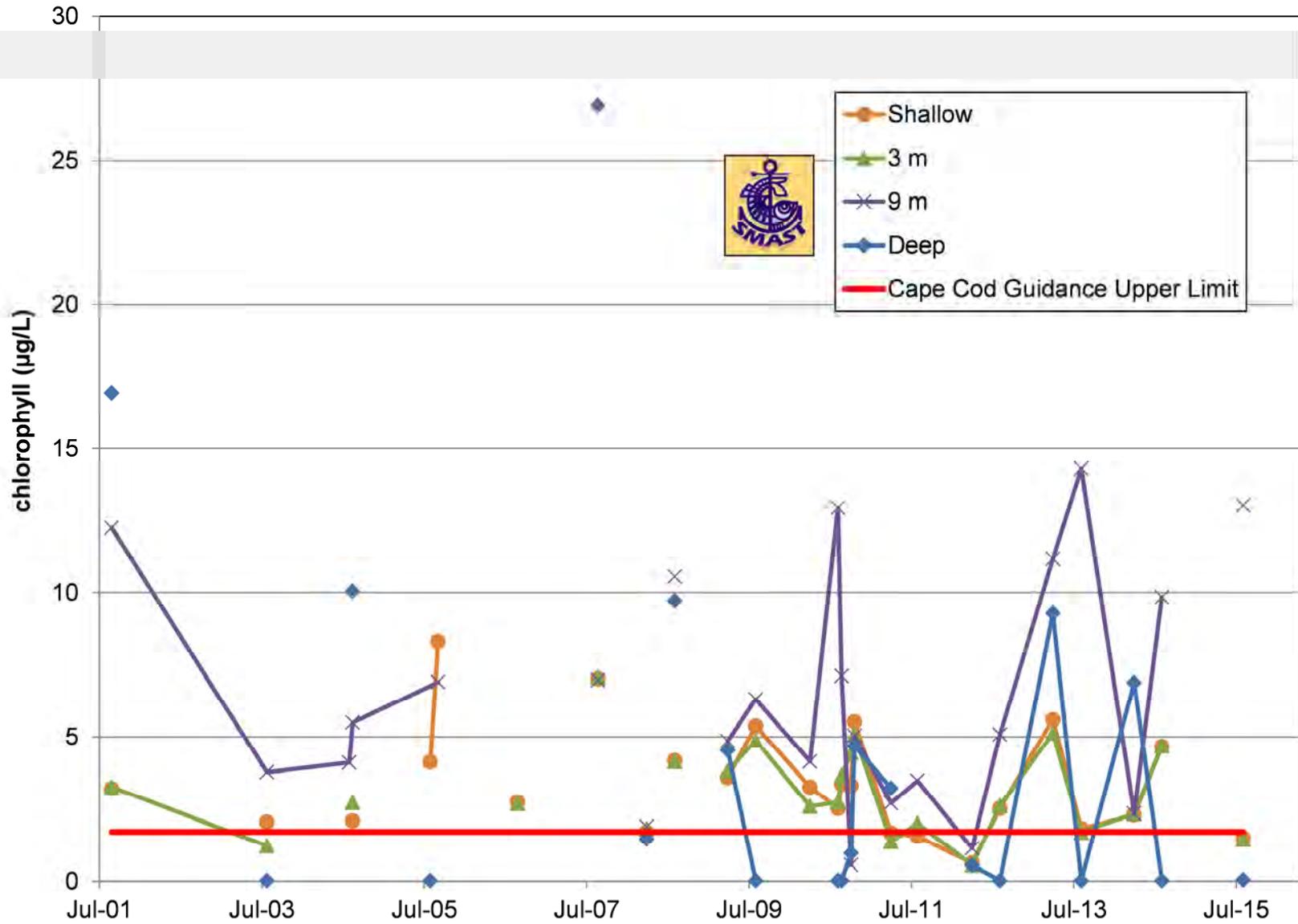
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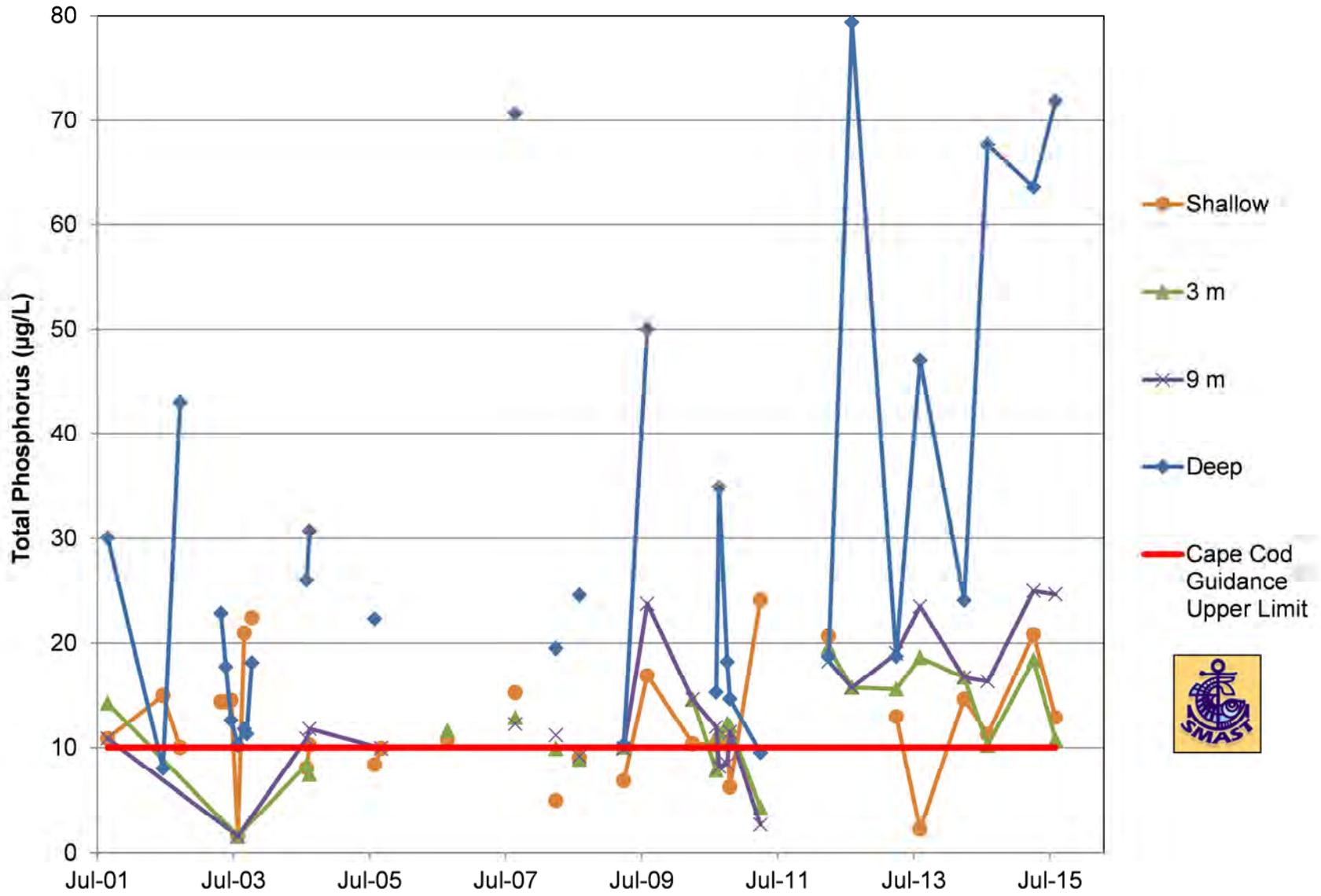
Scargo Lake: Dennis



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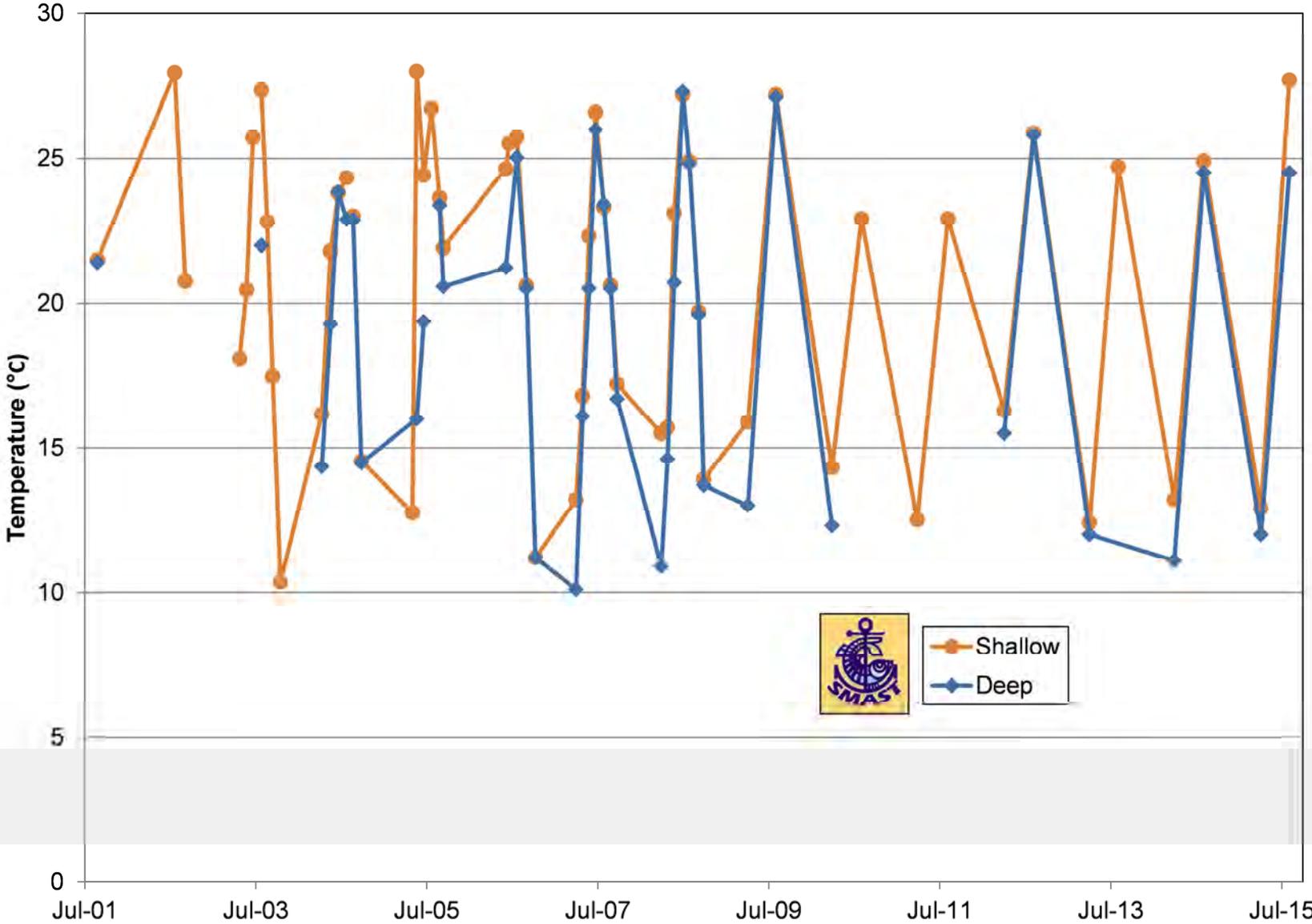


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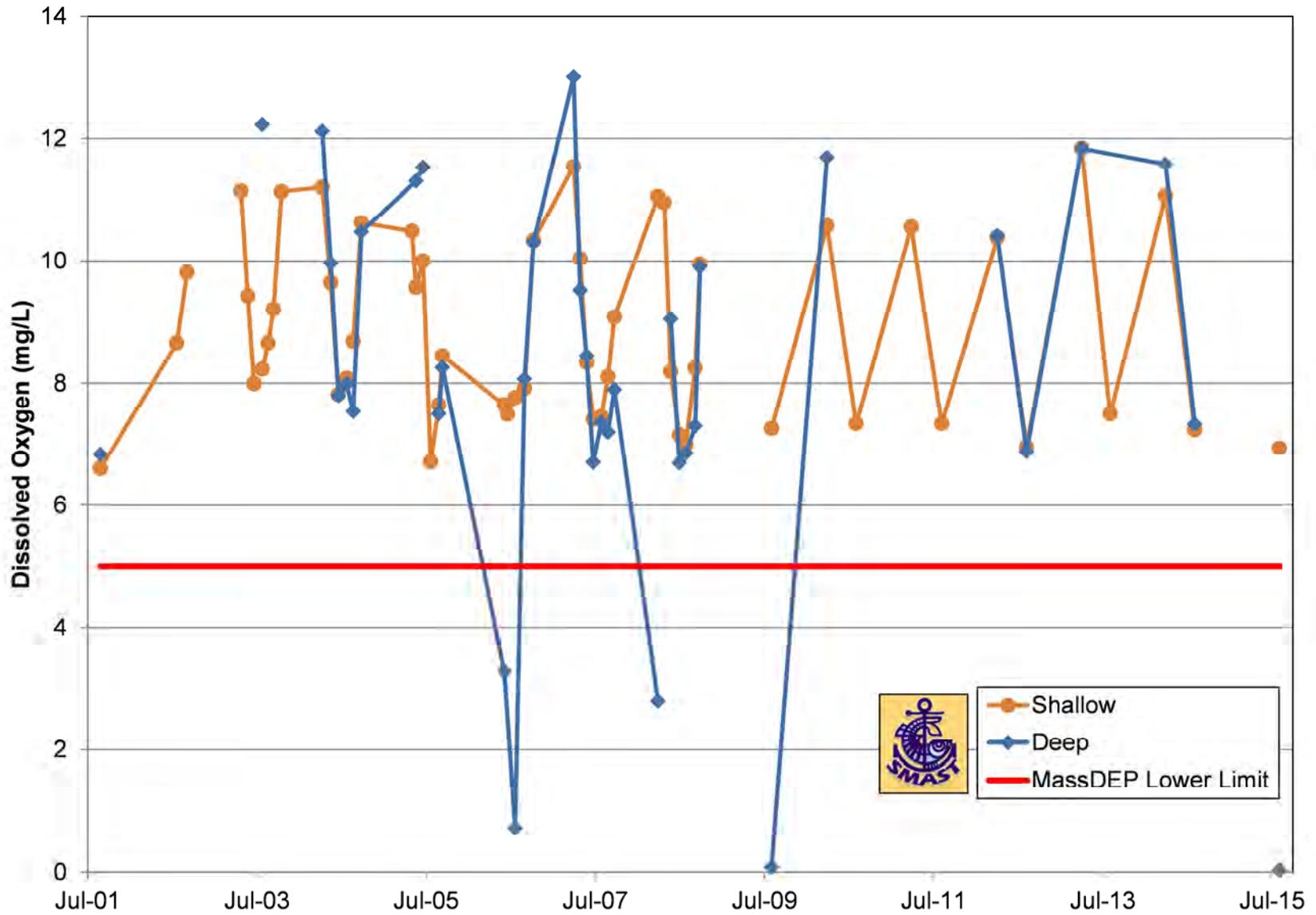


White Pond

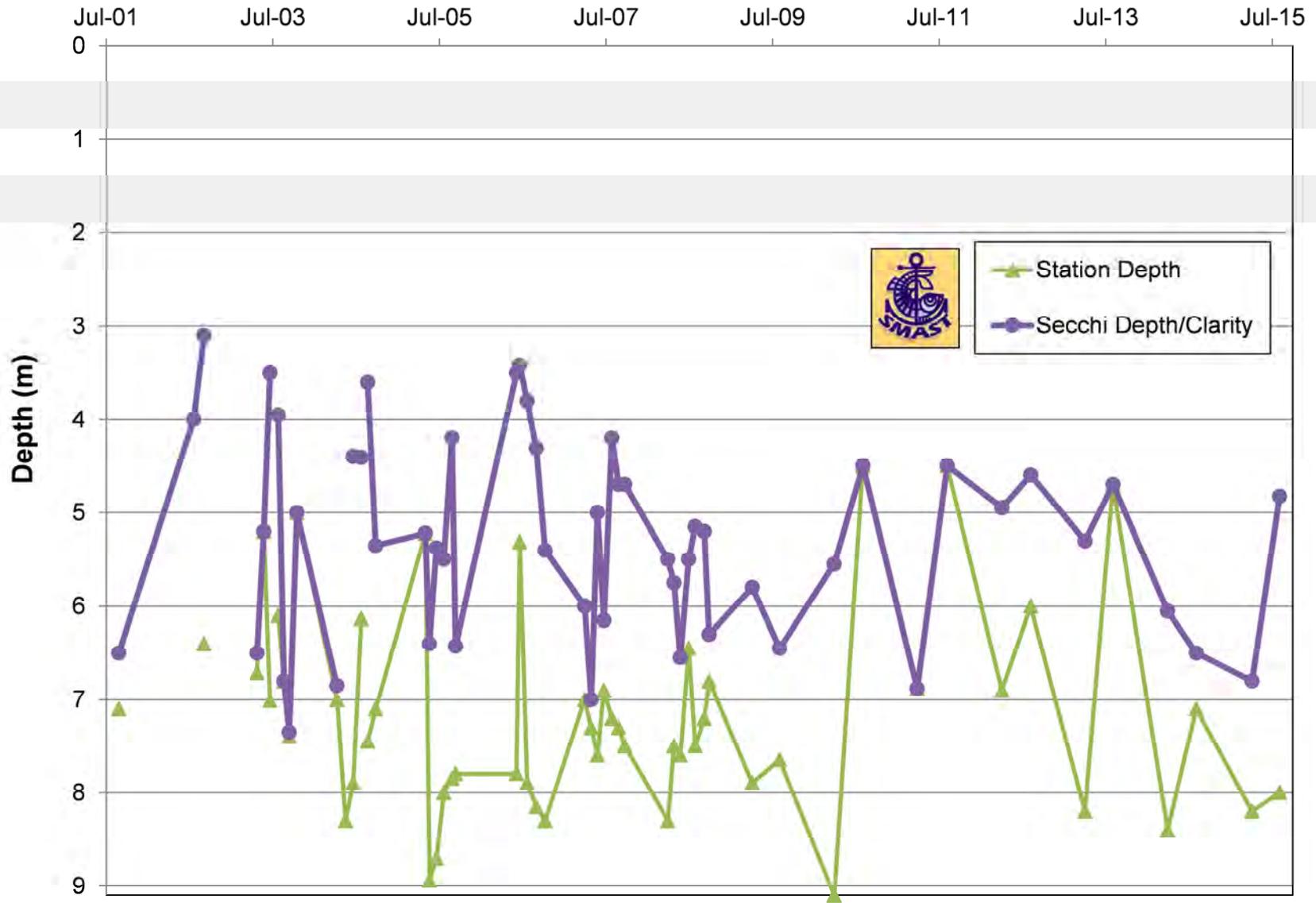
White Pond: Dennis



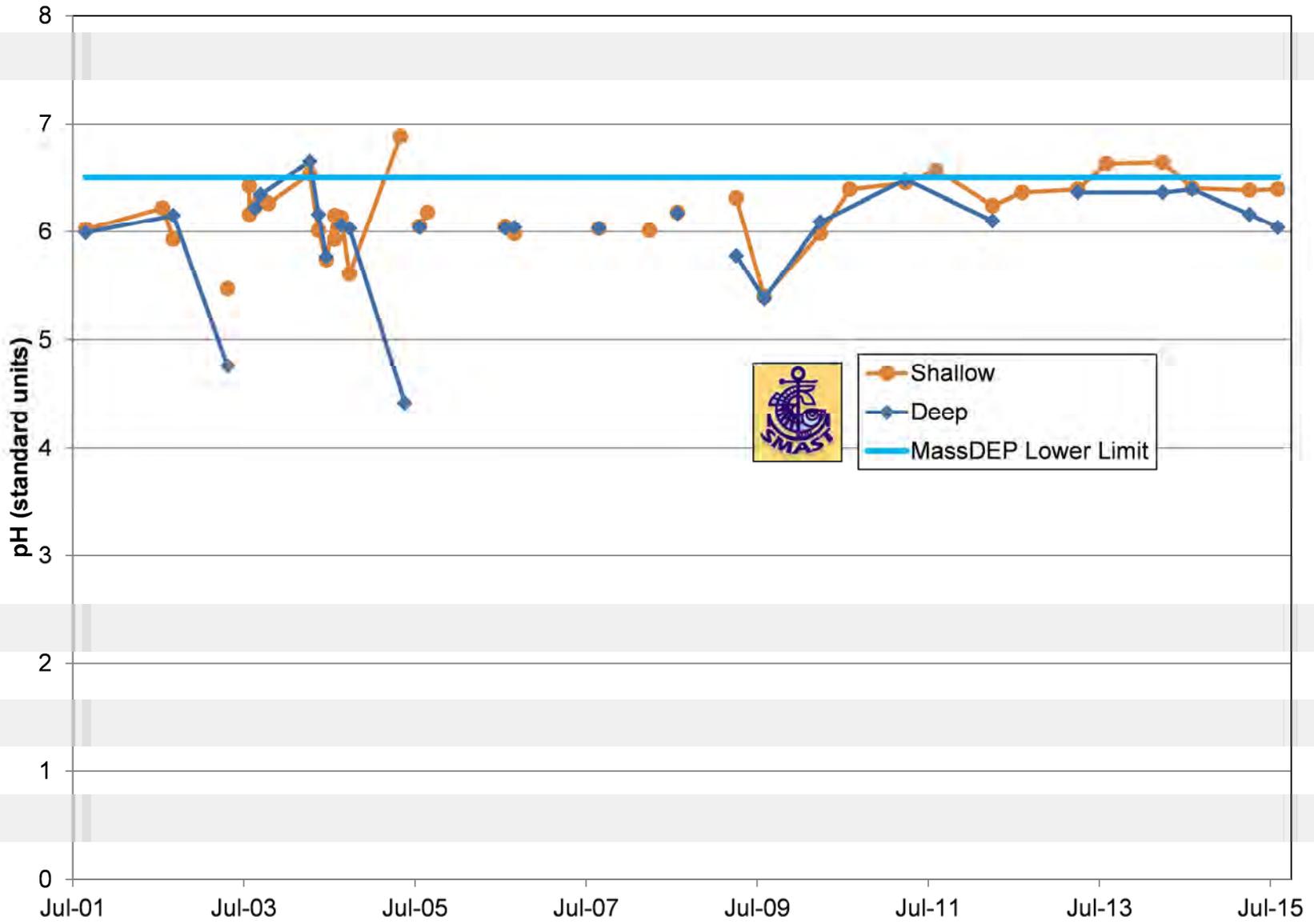
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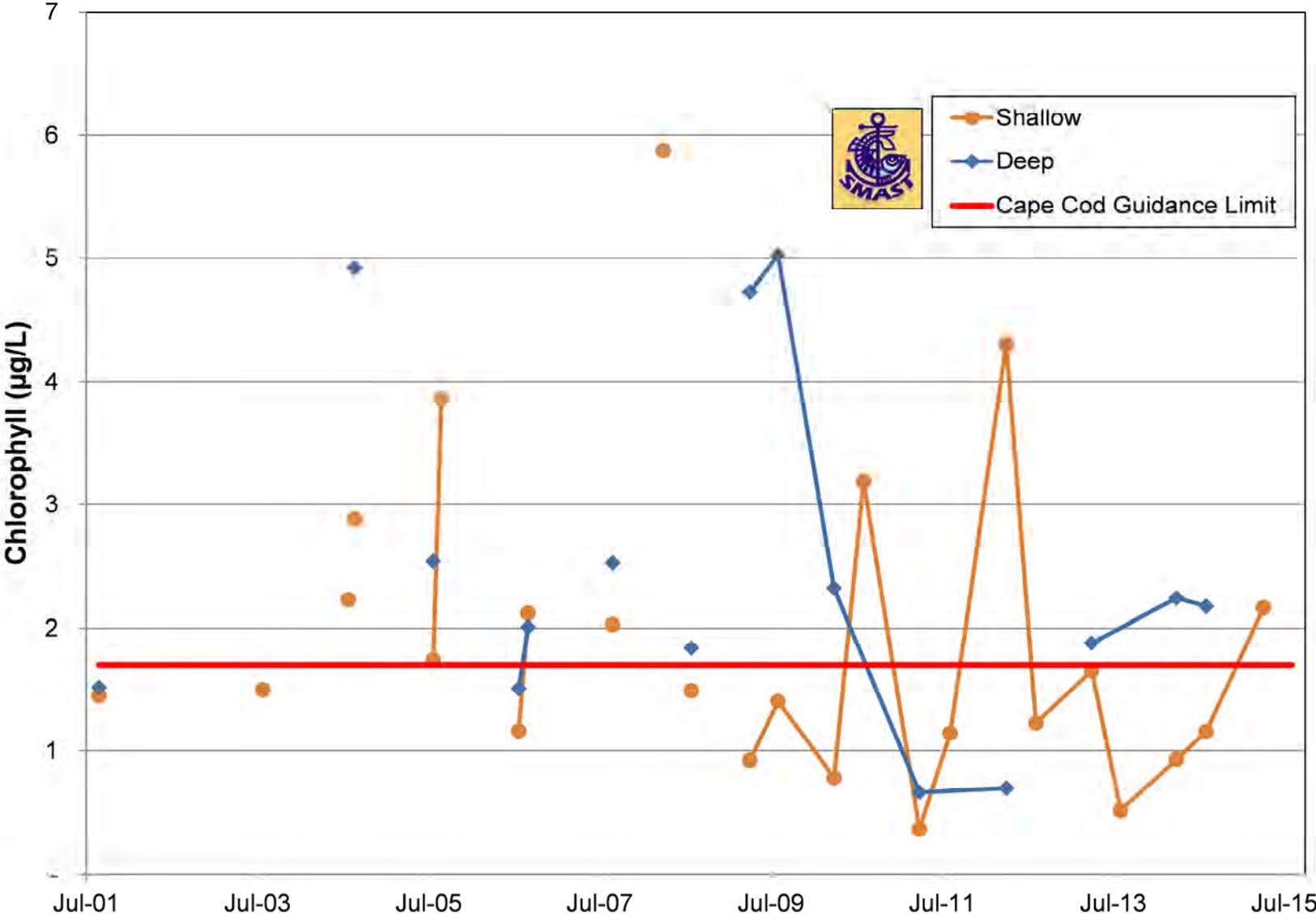
White Pond: Dennis



White Pond: Dennis



White Pond: Dennis



White Pond: Dennis

