Prepared in cooperation with the U.S. Fish and Wildlife Service–Region 2–National Wildlife Refuge System, the Havasu National Wildlife Refuge, and the Desert Landscape Conservation Cooperative

Assessment of Ecosystem Response to a Temporary Water Level Drawdown and Subsequent Refilling at Topock Marsh, Arizona—July 2011–October 2014

Open-File Report 2016–1195

U.S. Department of the Interior
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Cover. Photo 1—Cattail stand in Topock Marsh in September 2011 during low water conditions. Note how the cattail roots and rhizomes are above the water line and many of the leaves are brown. (Photo credit: Joan Daniels, U.S. Geological Survey) Photo 2—Cattail stand in Topock Marsh on April 20, 2014, during high water conditions. (Photo credit: Joan Daniels, U.S. Geological Survey)

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U.S. Geological Survey
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Abstract

Topock Marsh is a 1,637-hectare (4,045-acre) wetland adjacent to the Colorado River near Needles, California, and a main feature of Havasu National Wildlife Refuge (NWR). The U.S. Fish and Wildlife Service, in cooperation with the Bureau of Reclamation, began construction of an infrastructure improvement project in 2010 to increase the efficiency of water use and to help protect the habitats and species found within the Havasu NWR. During construction, normal water delivery from the Colorado River into Topock Marsh through the Inlet Canal was restricted, which resulted in unusually low water elevations in 2011. The U.S. Geological Survey, commissioned by the U.S. Fish and Wildlife Service, undertook the investigation of the water quality and aquatic flora and fauna during the low water conditions. Subsequently, water elevations in the marsh returned to more normal elevations after the new concrete-lined Fire Break Canal became fully operational in January 2012.

The U.S. Geological Survey made 11 field trips to the Havasu NWR between July 2011 and October 2014 to assess the effects of the temporary low water conditions and the change of inflow location (from the Inlet Canal to the Fire Break Canal) on water quality and aquatic habitat. The following conditions were monitored: water quality, sediment and plant chemistry, phytoplankton, zooplankton, aquatic macroinvertebrates, and emergent and submerged aquatic vegetation (SAV). Water-quality and biota data collected during 2013–14 were then compared with data collected during the 2011–12 low water period.

Once the new Fire Break Canal became operational and Colorado River water flowed regularly into the marsh, concentrations of several water quality parameters decreased (for example, specific conductance, total dissolved solids, turbidity, chlorophyll *a*, and total and organic nitrogen), and phytoplankton abundance was reduced at the upstream sampling stations (TP-3, TP-2, and TP-6); the water flow pushed water with higher concentrations of these components downstream (measured at TP-8). The upstream sampling locations in 2013–14 had decreased turbidity, therefore more SAV biomass accumulated, especially in shallow areas with water depths of ≤1.0 meter (≤3.3 feet). However, the furthest downstream station had higher turbidity caused by both the suspension of autochthonous sediment and high phytoplankton density and biovolume. This higher turbidity resulted in minimal SAV growth, especially in the deeper water (>1.0 meter [>3.3 feet]). Emergent vegetation not only survived the low water conditions of 2011, but expanded its areal coverage and subsequently thrived in the higher water elevations.

Overall, no immediate critically negative consequences were detected for aquatic fauna or flora that could be attributed unequivocally to the effect of low water levels. Concentrations of nutrient and trace elements in all water samples were below wildlife toxicity thresholds as established by Arizona Department of Environmental Quality. Three nonnative species were discovered shortly after the Fire Break Canal went into operation. Of the three, gizzard shad (*Dorosoma cepedianum*) and Eurasian watermilfoil (*Myriophyllum spicatum*) increased substantially in numbers from 2011–14, but quagga mussels (*Dreissena bugensis*) did not increase. Future monitoring will determine the long-term impact of the new flow regime.

Introduction

The marshes and other wetland areas of Topock Marsh within the Havasu National Wildlife Refuge (NWR) were created and maintained by the dynamic flows of the Colorado River before construction of major dams and diversions. Throughout the 20th century, the river was regulated through a series of water development projects that changed the flow dynamics and reduced the frequency and magnitude of floods and droughts that characterized the unregulated river (U.S. Department of the Interior [DOI], 2009). Under the regulated flow regime, many fish and wildlife species that were adapted to the natural conditions became threatened, endangered, or of special concern to Federal and State resource management agencies (DOI, 2009).

In 1941, Executive Order 8647 was issued by President Franklin Roosevelt to establish Havasu NWR for use by the Department of the Interior as a refuge and breeding ground for migratory birds and other wildlife (6 *Federal Register* 593; January 25, 1941) (Roosevelt, 1941). During the years since then, various canals, dikes, and ditches were constructed (fig. 1) to help maintain the marsh's original function (U.S. Fish and Wildlife Service, 1966; Shoreline Engineering and Restoration, 2006). A more complete chronology of the history of the marsh and its hydrology is presented in Guay (2001). To address the deterioration of the water management infrastructure and changes in the physical characteristics and management of the Colorado River, the U.S. Fish and Wildlife Service (FWS) initiated an infrastructure improvement project in cooperation with the Bureau of Reclamation. The project was designed to enable managers to better control water levels in an effort to protect and improve the current habitat for species of special interest and special status (threatened, endangered, or candidate species), as well as habitats for common species that use the Havasu NWR (DOI, 2009). During construction of the new infrastructure, inflows into Topock Marsh were maintained at lower than usual levels (fig. 2*A*), which resulted in below-average water depths throughout 2011, as measured as water elevations at the outlet structure in the South Dike (fig. 2*B*). Consequently, the FWS commissioned assistance from the U.S. Geological Survey (USGS) to assess the aquatic biotic and abiotic condition of the marsh during these unusually low water levels.

In addition to measuring water-quality conditions and comparing them to previous water-quality data collected by Reclamation, the assessment was conducted to learn how the aquatic flora and fauna responded to the low water conditions and, subsequently, how hydrologic manipulation by means of the new infrastructure could affect ecological management and restoration. Habitats specifically identified for species protection within the marsh include those that support the fully protected and threatened black rail (*Laterallus jamaicensis coturniculus*), the endangered Ridgway's rail (*Rallus obsoletus yumanensis*, formerly Yuma clapper rail), Southwestern willow flycatcher (*Empidonax traillii extimus*), and razorback sucker (*Xyrauchen texanus*), as well as other species listed in the draft environmental assessment for the Topock Marsh water infrastructure improvement project (DOI, 2009). Therefore, sampling efforts were focused on monitoring representative areas that would potentially be used by these species.

In addition to USGS's water quality and aquatic flora and fauna monitoring of Topock Marsh during low water conditions and immediately after higher flow was restored, FWS needed to better understand the health and function of Topock Marsh under various hydrologic conditions. With funding provided by the FWS Desert Landscape Conservation Cooperative, USGS developed a decision support system (DSS) using a spatially explicit geographic information system package of historical data, habitat indices, and analytical tools to synthesize outputs for varying hydrologic conditions.

The first phase of the Havasu NWR DSS, called Phase 1 (hindcasting model), was developed to be used by the refuge managers to compare habitat availability associated with three historical hydrologic scenarios (historical dry, average, wet years) along with additional proposed operations of interest by specifying a range of marsh water surface elevations (WSEs) throughout the year (Holmquist-Johnson and others, 2016). Phase 1 of the DSS does not explicitly model the quantity of water delivered from the Colorado River through the various canals to the marsh that is required to meet a given marsh elevation. Instead, a hindcasting-type analysis is used to determine the total volume of water that must be added or subtracted throughout the year to meet a prescribed range of marsh elevations. The total volume of water required to meet a given hydrologic scenario can then be used by refuge managers, along with Reclamation engineers, to determine the availability of Colorado River water and the most efficient method of delivering water to the marsh. A detailed description of the types of outputs that are available from the Phase 1 DSS can be found in Holmquist-Johnson and others (2016). A number of predefined views are available that provide a starting point for users in analyzing the effects of marsh elevations on available habitat and water storage and inflow requirements at Topock Marsh. For example, the "habitat versus water surface elevation curves" view provides a summary plot of suitable habitat using the habitat suitability criteria described by Bovee (1986) for a given species and life stage as a function of marsh elevation. Additionally, the "summary habitat results—all scenarios" view provides a bar chart showing the mean annual available habitat for six species within each management scenario compared to the historical average baseline.

Although the DSS does not produce any specific biological output (that is, clutch size, plant growth, or juvenile survival), it does provide a tool to identify relative effects of water operations on ecological processes and species-specific habitats that can be used by Havasu NWR staff and managers. The DSS also provides the data discussed in this report as additional information for the user to assist them in determining what might happen under various scenarios based on historical conditions and trends. The adaptability of the DSS tool as time goes on is one of the DSS's most valuable capabilities. To continue to improve on the work that has been conducted at Topock Marsh, USGS, FWS, Reclamation, and other science partners could continue to collaborate and work towards developing a Phase 2 (forecasting model) of the Havasu NWR DSS. This Phase 2 DSS would build on the current Phase 1 hindcasting model DSS and would incorporate output from water management operations and hydrodynamic (water quantity and quality) modeling based on marsh bathymetry, Colorado River hydrology, and future water delivery methods. The data presented in this report could be used to provide vital information in calibration and validation of a water-quality model for Topock Marsh. The output from the water-quality model could then be used by the Phase 2 DSS as inputs to assess how various marsh scenarios might affect the water-quality conditions throughout the marsh. Synthesis of

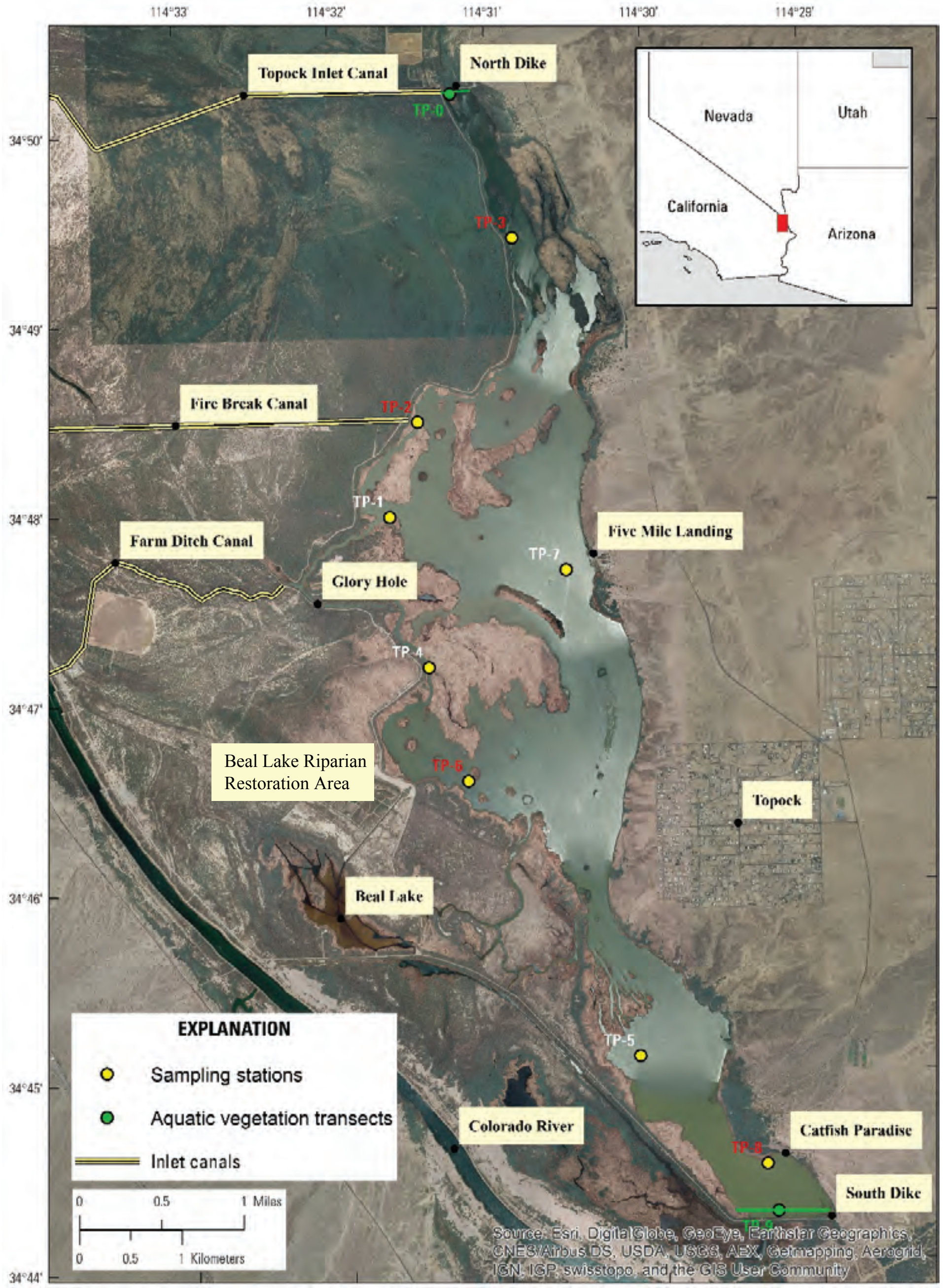

Figure 1. Location of 3 water irrigation canals (Topock Inlet, Fire Break, and Farm Ditch) and 10 biotic and abiotic sampling stations within Topock Marsh, Arizona. The sampling stations are denoted as TP-0 through TP-9. Four sampling stations shown in red (TP-3, TP-2, TP-6, and TP-8) are 2011–14 U.S. Geological Survey sample collection locations. Aquatic vegetation data were collected along two transects, TP-0 and TP-9 (shown as green lines).

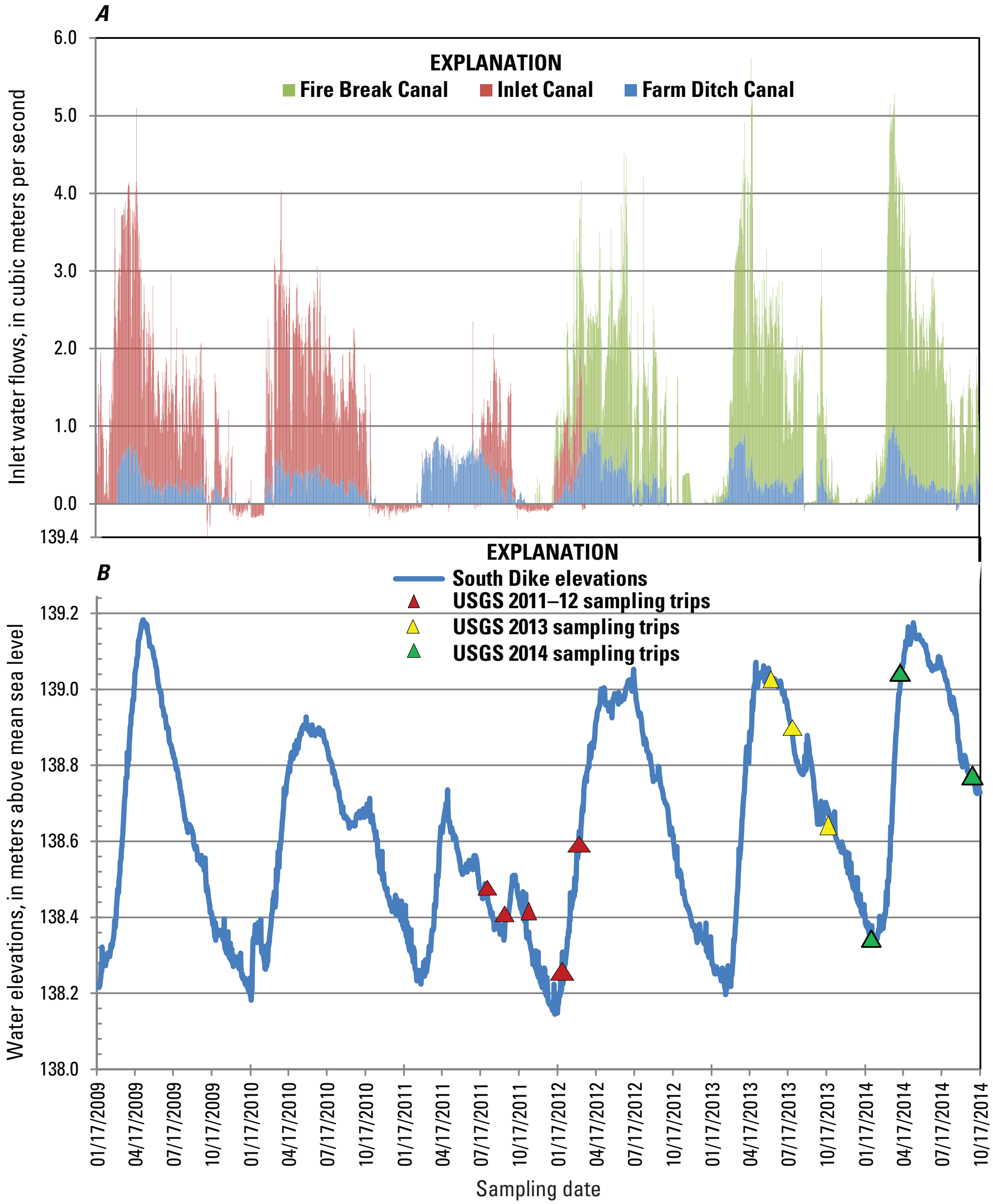

Figure 2. Topock Marsh, Arizona, inlet flows and water elevations at the South Dike from January 2009 to October 2014. *A*, Topock Marsh inlet flows and *B*, water elevations at the South Dike. (USGS, U.S. Geological Survey)

these additional model outputs would allow FWS to compare different hydrologic scenarios, water management operations and delivery methods, and their influences on species-specific habitat. Once these tools are developed, they could be valuable for, and directly applicable to, future analysis needs that could include indepth evaluation of climate change effects.

In summary, the specific objectives of the data reported herein were to 1) determine the status of the marsh during the 2011 low waterflow period, 2) assess whether use of the new Fire Break Canal and closing of the Inlet Canal in 2012 impacted the water quality and (or) aquatic biota in the marsh compared to previous years, and 3) provide 2011–14 water-quality and aquatic flora and fauna data as additional information to the DSS user to assist them in determining what might happen under various scenarios based on historical conditions and trends.

Site Description

Topock Marsh is located in the Mojave Desert adjacent to, and on the east side of, the Colorado River between Needles, California, and Lake Havasu City, Arizona (fig. 1). The marsh is approximately 16 kilometers (km) (9.9 miles [mi]) long and 3 km (1.9 mi) wide at its widest point and the surface area of the wetland is 1,637 hectares (4,045 acres) (Guay, 2001). The Colorado River is regulated by Davis Dam, which is located approximately 64 km (39.8 mi.) upstream of the marsh. Colorado River water is delivered through the earthen Farm Ditch Canal, which was built in 1968 on the marsh's west side, and the Fire Break Canal, which was completed in September 2011 and has operated consistently since January 2012 (figs. 1 and 2). Inflow from the Inlet Canal (figs. 1 and 2*A*), which was built in 1965 at the marsh's northern end, was closed off in March 2012 primarily because of the large water loss through the 6.6 km (4.1 mi.) earthen canal and mixed land ownership issues (DOI, 2009).

Historically, all water flowed into the marsh by gravity feed and moved from north to south parallel to the Colorado River. The infrastructure was built to allow the marsh to drain through an outlet structure in the South Dike, which was built in 1965. Little to no outflow occurred during the July 2011–October 2014 USGS sampling period, as shown by the Reclamation's water gage data available at http://www.usbr.gov/lc/region/g4000/riverdata/gage-map3-text.cfm.

However, there was some waterflow that came into the marsh through the South Dike, which is normally used as the outflow, so it registered as negative flow numbers (fig. 2*A*).

Weather at Topock Marsh is typically hot and dry during the summer months (June, July, and August). The maximum air temperature reached 50.6 degrees Celsius (°C) (123 degrees Fahrenheit [°F]) on June 29, 2013 between the two summer 2013 sampling trips and total precipitation was 0.28 centimeters (cm) (0.11 inches [in.]) during that time. The minimum air temperature recorded was –2.2 °C (28.0 °F) in January 2013, but the mean annual low temperature was 18.3 °C (64.9 °F) (fig. 3*A*). The prevailing winds are typically from the north and northwest during winter months (December, January, and February) and from the south and southwest during the summer months. The maximum wind gust during the study period occurred in July 2014 and was 114.3 km per hour (km/h) (71.0 miles per hour [mi/h]) (fig. 3*B*). The maximum monthly precipitation during the study period was 7.24 cm (2.85 in.) in August 2013; no monthly precipitation was recorded during January, May, June, and November 2012; April, May, and June 2013; and January, March, May, and June 2014 (National Oceanic and Atmospheric Administration, 2016; Weather Underground, 2016; WeatherSpark Beta, 2016).

Methods

Sampling Schedule and Waterflow Data Records

Eleven individual sampling events were conducted between July 25, 2011, and October 7, 2014, and additional in situ physicochemistry measurements were collected during December 2013. These events are marked on figure 2*B*. Specific sampling activities are listed in tables 1 and 2. Dates of sampling trips; WSEs, as measured at the outlet structure in the South Dike; and waterflow rates are listed in table 3. During this study period, the WSEs ranged from 138.14 meters (m) (453.22 feet [ft]) above mean sea level (amsl) on January 10, 2012, to 139.18 m (456.63 ft) amsl on May 11, 2014. Waterflow through the Farm Ditch Canal, Inlet Canal, and the South Dike and WSE data were obtained from Reclamation gage data (http://www.usbr.gov/lc/region/g4000/riverdata/gage-map3-text.cfm) and verified by Reclamation personnel. Flow rates for the Fire Break Canal were obtained from USGS gage data (U.S. Geological Survey, 2016a, http://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=09423560&agency_cd=USGS). Total flows into the marsh and WSEs at the South Dike outlet structure are shown in figures 2*A* and 2*B* for the period January 2009–October 2014.

Sample Locations

Four sampling stations were selected within the marsh along the upstream to downstream gradient: TP-3, TP-2, TP-6 and TP-8 (see fig. 1). These sampling stations, which were all accessible by boat, were selected from eight sites previously selected by FWS biologists to characterize various habitat types along the marsh shoreline from inlet to outlet from the Arizona Fish and Wildlife Conservation Office (AZFWCO) in Parker, Arizona. Station TP-3 is the most northern of the sampling stations and closest to the Inlet Canal. TP-2 is located where the flow from the Fire Break Canal enters the marsh. TP-6 is along the western edge of the marsh near the Beal Lake Riparian Restoration Area. TP-8 is the southernmost sampling station and is located 195 m (640 ft) northwest of the Catfish Paradise boat launch and directly north and upstream of the South Dike outlet.

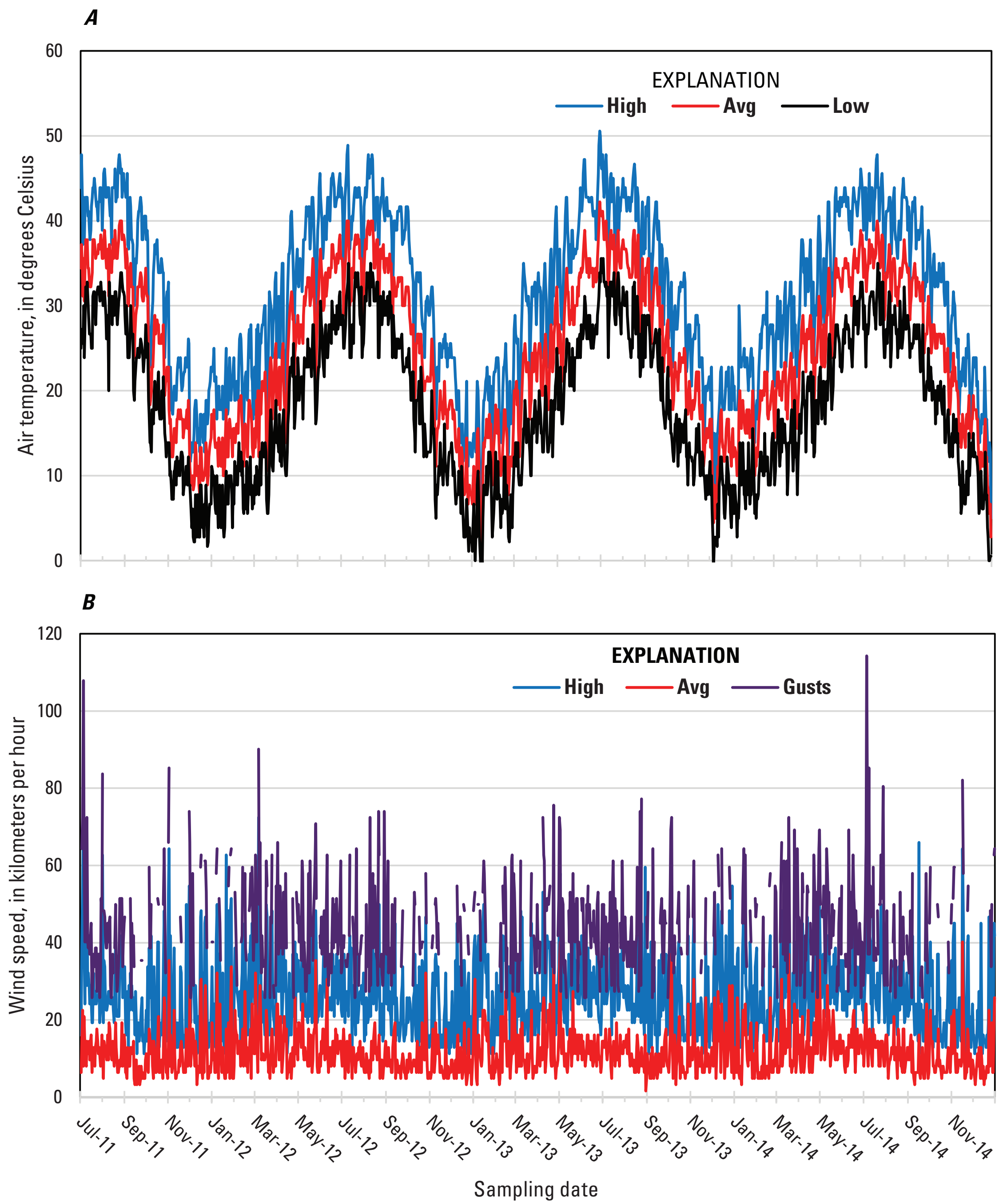

Figure 3. Air temperature (*A*) and wind speed (*B*) recorded at the Needles Airport, California, weather station (National Oceanic and Atmospheric Administration, 2016) from July 1, 2011 to December 31, 2014.

Table 1. Parameters and specific data sampled within Topock Marsh from July 2011 to October 2014.

[SC, specific conductance; DO, dissolved oxygen; NH_3-N, ammonia-nitrogen; NO_3, nitrate; NO_2-N, nitrite nitrogen; Org-N, organic nitrogen; TN, total nitrogen; TP, total phosphorus; TSS, total suspended solids; SS, volatile-on-ignition suspended solids; As, arsenic; B, boron; Ca, calcium; Cd, cadmium; Cl, chlorine; Cr, chromium; Cu, copper; F; fluoride; Fe, iron; Hg, mercury; K, potassium; Mg, magnesium; Mn, manganese; Na, sodium; Pb, lead; Se, selenium; Zn, zinc; SO_4, sulfate; TDS, total dissolved solids; CO_3, carbonate; HCO_3, bicarbonate; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; EC, electrical conductivity; %, percentage; OM, organic matter; NO_3-N, nitrate-nitrogen; P, phosphorus; S, sulfur; Mo, molybdenum; N, nitrogen; Al, aluminum; sUAS, small unmanned aircraft system]

Parameters	Specific data collected	Equipment and methods used
In situ spot check of physicochemistry	Temperature, pH, SC, DO, turbidity	Hydrolab® Quanta
In situ diurnal physicochemistry	Temperature, pH, SC, DO, some turbidity	Hydrolab® MiniSondes
In situ water transparency	Depth of Secchi disk visibility	Secchi disk
Water chemistry		
—Nutrients and other parameters	NH_3-N, NO_3+NO_2-N, Org-N, TN, TP, alkalinity, TSS, SS, chlorophyll *a*	Sample bottles, preservatives, water column sampler, ice (no preservative), freeze
—Elemental and ion analyses	As, B, Ca, Cd, Cl, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Na, Pb, Se, Zn, and SO_4	Sample bottles, preservative, ice
—Historical water chemistry, 1983–2015	Temperature, depth gage, SC, TDS, pH, Na, K, Ca, Mg, CO_3, HCO_3, alkalinity (as $CaCO_3$), Cl, SO_4, SiO_2, F, NO_3+NO_2-N, NO_3, and hardness (as $CaCO_3$).	Water samples collected monthly and analyzed by the Bureau of Reclamation, Lower Colorado Region
Sediment chemistry	pH; EC; lime; % OM, texture; NO_3-N, P, K, Zn, Fe, Mn, Cu, As, Se, Hg, S, B, and either Cr , Cd, Pb, Mo or Ca, Mg, and Na	Sample bags, ice
Plant chemistry	N, Ca, Mg, Na, K, P, S, Fe, Mn, Cu, Zn, B, NO_3-N, Al, As, Hg, Mo, Se, Cr, and % dry matter	Sample bags, ceramic knife, ice
Plankton	Phytoplankton and zooplankton	Water column sampler, plankton net, preservative
Small biota near shore	Macroinvertebrates and crayfish	D-nets, crayfish traps, preservative
Plant surveys	Submerged and emergent plants	Boat transects, snorkel gear, underwater camera, depth rod, sUAS and equipment

Water-Quality Characteristics—Protocol and Equipment

Physicochemistry

Vertical profiles of physicochemical parameters were collected at the four sampling stations using an instantaneous in situ instrument (Hydrolab® Quanta) that was calibrated before each sampling trip. The Hydrolab® Quanta measured water temperature in °C, pH in standard units, dissolved oxygen (DO) in milligrams per liter (mg/L), specific conductance (SC) in microsiemens per centimeter (µS/cm at 25 ºC), total dissolved solids (TDS) in mg/L, and turbidity in nephelometric turbidity units (NTUs). The vertical profile consisted of measurements taken at 0.05–0.10 m (2.0–3.9 in.) below the water surface and at 0.5 m (1.6 ft) increments to just above the sediment floor (marsh bottom). During 2013–14, measurements were also taken at 0.2 m (7.9 in.) (or 0.3 m [11.8 in.] in April 2014) below the surface at sites with water depths of ≤1.0 m (≤3.3 ft). Extreme values for DO and turbidity were caused by sediment disturbance by the instrument as it accidently contacted the soft marsh bottom. When this occurred and there was a more than 45 NTU increase from the previous value, those values were not included on the figures. Water clarity was estimated using a Secchi disk; the Secchi depth, measured to the nearest 0.01 m (2 in.) at the time of vertical profile sampling, was compared to turbidity measurements for an inverse verification (that is to say, a higher Secchi depth relates inversely to a lower turbidity value). Turbidity is a measure of water clarity as it relates to how much the material suspended in the water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances (Kadlec and Wallace, 2009).

Freshly calibrated datalogging multiparameter instruments (Hydrolab® MiniSonde 4a and 5a) were deployed at the four sample stations during each sampling trip (table 2) to measure diurnal physicochemistry. Each of the units was programmed to record water temperature, pH, DO, SC, salinity, and TDS at hourly intervals. In 2013, two MiniSonde 5 as were outfitted and deployed with turbidity probes set to measure and record hourly, and those data were used to compare to the Quanta turbidity measurements and to Secchi disk readings. Deployment periods varied by the number of days we were in the field (2.5–8 consecutive days). The MiniSondes were secured at mid-water column depths either to sampling station buoys, large cinder blocks anchored to the marsh bottom, or the nearest tree snag.

Table 2. Dates, analyses, and locations where the various samples were taken in Topock Marsh from July 2011 through October 2014.

[TP, sampling station; Jl, July; S, September; O[1], October 2011; JF, January/February; M, March; Jn, June; O[3], October 2013, D, December; F, February; Ap, April; O[4], October 2014; typ., typically; AGFD, Arizona Game and Fish Department]

Data collected	TP-3											
	2011			2012		2013				2014		
	Jl	S	O[1]	JF	M	Jn	Jl	O[3]	D	F	Ap	O[4]
In situ spot check of physiochemistry	X	X	X	X	X	X	X	X	X	X	X	X
In situ diurnal physiochemistry	X	X	X	X	X	X	X	X	X	X	X	X
+ including diurnal turbidity						X	X	X		X	X	X
In situ water transparency	X	X	X	X	X	X	X	X		X	X	X
Water chemistry												
Nutrients and other parameters	X	X	X	X	X	X	X	X		X	X	X
Elemental analyses, *ions*			X*X*				X	*X*				X*X*
Sediment chemistry			X				X					X
Plant chemistry							X					X
Chlorophyll *a*	X	X	X	X	X	X	X	X		X	X	X
Plankton												
Phytoplankton		A	X	X	X	X	X	X		X	X	X
Zooplankton		A	X	X	X	X	X	X		X	X	X
Small biota near shore												
Macroinvertebrates		X	X	X	X	X	X	X		X	X	X
Crayfish	X	X	X	X	X		X	X				
Plant surveys												
Submerged (typ. along TP-3, 2, 1, 6, or 8)		X	X[a]	X			X	X				X
Emergent—aerial survey												X
Fish surveys												
Gill nets— with AGFD	F			F		F				F		

Data collected	TP-2											
	2011			2012		2013				2014		
	Jl	S	O[1]	JF	M	Jn	Jl	O[3]	D	F	Ap	O[4]
In situ spot check of physiochemistry	X	X	X	X	X	X	X	X	X	X	X	X
In situ diurnal physiochemistry	X	X	X	X	X	X	X	X	X	X	X	X
+ including diurnal turbidity									X			
In situ water transparency	X	X	X	X	X	X	X	X		X	X	X
Water chemistry												
Nutrients and other parameters	X	X	X	X	X	X	X	X		X	X	X
Elemental analyses, *ions*			X*X*				X	*X*				X*X*
Sediment chemistry			X				X					X
Plant chemistry							X					X
Chlorophyll *a*	X	X	X	X	X	X	X	X		X	X	X
Plankton												
Phytoplankton		A	X	X	X	X	X	X		X	X	X
Zooplankton		A	X	X	X	X	X	X		X	X	X
Small biota near shore												
Macroinvertebrates		X	X	X	X	X	X	X		X	X	X
Crayfish	X	X	X	X	X		X	X				
Plant surveys												
Submerged (typ. along TP-3, 2, 1, 6, or 8)		X	X[a]	X	X[b]		X	X				X
Emergent—aerial survey												X
Fish surveys												
Gill nets— with AGFD	F			F		F				F		

Data collected	TP-6											
	2011			2012		2013				2014		
	Jl	S	O[1]	JF	M	Jn	Jl	O[3]	D	F	Ap	O[4]
In situ spot check of physiochemistry	X	X	X	X	X	X	X	X		X	X	X
In situ diurnal physiochemistry	X	X		X	X	X	X	X		4	X	X
+ including diurnal turbidity						X	X			2	X	
In situ water transparency	X	X	X	X	X	X	X	X		X	X	X
Water chemistry												
Nutrients and other parameters	X	X	X	X	X	X	X	X		X	X	X
Elemental analyses, *ions*			X*X*				X	*X*				X*X*
Sediment chemistry			X				X					X
Plant chemistry							X					X
Chlorophyll *a*	X	X	X	X	X	X	X	X		X	X	X
Plankton												
Phytoplankton		A	X	X	X	X	X	X		X	X	X
Zooplankton		A	X	X	X	X	X	X		X	X	X
Small biota near shore												
Macroinvertebrates		X	X	X	X	X	X	X		X	X	X
Crayfish	X	X	X	X	X		X	X				
Plant surveys												
Submerged (typ. along TP-3, 2, 1, 6, or 8)	X	X		X	X		X	X				X
Emergent—aerial survey												X
Fish surveys												
Gill nets— with AGFD	F			F		F				F		

Data collected	TP-8											
	2011			2012		2013				2014		
	Jl	S	O[1]	JF	M	Jn	Jl	O[3]	D	F	Ap	O[4]
In situ spot check of physiochemistry	X	X	X	X	X	X	X	X		X	X	X
In situ diurnal physiochemistry	X		X	X	X	X	X	X	X	X	X	X
+ including diurnal turbidity						X		X				X
In situ water transparency	X	X	X	X	X	X	X	X		X	X	X
Water chemistry												
Nutrients and other parameters	X	X	X	X	X	X	X	X		X	X	X
Elemental analyses, *ions*			X*X*				X	*X*				X*X*
Sediment chemistry			X				X					X
Plant chemistry							X					X
Chlorophyll *a*	X	X	X	X	X	X	X	X		X	X	X
Plankton												
Phytoplankton		A	X	X	X	X	X	X		X	X	X
Zooplankton		A	X	X	X	X	X	X		X	X	X
Small biota near shore												
Macroinvertebrates		X	X	X	X	X	X	X		X	X	X
Crayfish	X	X	X	X	X		X	X				
Plant surveys												
Submerged (typ. along TP-3, 2, 1, 6, or 8)	X	X	X[a]				X	X				X[c]
Emergent—aerial survey												X
Fish surveys												
Gill nets— with AGFD	F			F		F				F		

Notes:

A = August collection
X = *ion analyses*
F = February collections

X[a] = surveys taken along TP-0, TP-1, and TP-9, instead
X[b] = surveys also taken along TP-5
X[c] = survey also taken along TP-9

4 = only four hours of data storage
2 = only two hours of data storage

Table 3. Topock Marsh average water surface elevations and average waterflow rates during each biotic and abiotic sampling trip from July 2011 through October 2014.

[Water surface elevations and flow rates were published online by the Bureau of Reclamation and subsequently averaged by the U.S. Geological Survey for each sampling period. WSE, water surface elevation; WFR, waterflow rate; m, meter; amsl, above mean sea level; ft, foot; m^3/s, cubic meter per second; ft^3/s, cubic foot per second]

Sampling dates	WSE m amsl	WSE ft amsl	WFR m^3/s	WFR ft^3/s
July 25–29, 2011	138.48	454.33	2.107	74.400
September 21–23, 2011	138.41	454.10	1.044	36.867
October 23–27, 2011	138.43	454.16	0.039	1.380
January 30–February 2, 2012	138.25	453.58	0.968	34.196
March 6–9, 2012	138.60	454.73	2.284	80.670
June 10–14, 2013	139.03	456.12	2.478	87.520
July 21–25, 2013	138.91	455.73	1.135	40.080
October 28–31, 2013	138.64	454.86	0.348	12.300
December 12–18, 2013*	138.50	454.41	0.006	0.200
February 10–14, 2014	138.35	453.89	0.266	9.398
April 14–22, 2014	139.08	456.30	3.516	124.175
September 29–October 7, 2014	138.75	455.23	0.888	31.368

*Only in situ water quality monitoring at TP-3 and TP-2 occurred during this trip.

Chlorophyll *a*, Nutrients, Major Ions, and Trace Elements

Water samples for determining chlorophyll *a* content were obtained during each of the 11 sampling trips. The entire water column was sampled with a weighted flexible pool hose, as described in Lieberman and Grabowski (2007). The water column sample was mixed in a clean bucket and divided into two parts for separate chlorophyll *a* and phytoplankton analyses (see the "Phytoplankton and Zooplankton" section of this report for additional information). Each chlorophyll *a* sample was filtered onto a 47-millimeter (1.85 in.) glass-fiber/circle filter, with a particle retention of 1.2 micrometers (µm) (0.000047 in.), and kept frozen and in the dark until analysis. Chlorophyll *a* analyses were performed by Reclamation's Lower Colorado (LC) Regional Laboratory in July and September 2011, and by Reclamation's Water and Environmental Resources Division Environmental Applications & Research Laboratory the other nine times, according to standard methods described in American Public Health Department and others (1995).

Water samples for all other analyses were collected from just under the water surface at the 4 sampling stations during each of the 11 sampling trips. Total suspended solids (TSS); alkalinity, as calcium carbonate; total phosphorus (TP); total Kjeldahl nitrogen, which is ammonia ($NH_{3)}$ + organic nitrogen (Org-N); ammonia-nitrogen (NH_3-N); and total nitrogen (TN) (table 1) were analyzed for each sampling trip, except that TSS and alkalinity were not analyzed for July 2013. Organic nitrogen was calculated by subtracting NH_3-N from total Kjeldahl nitrogen. Nitrate + nitrite nitrogen (NO_3+ NO_2-N) values were calculated by subtracting total Kjeldahl nitrogen from TN. Water samples collected in 2011 were prepared and preserved for analysis by Reclamation's LC Regional Laboratory in Boulder City, Nevada, according to standard operating procedures as described by Eaton and others (2005). All water samples collected in 2012, 2013, and 2014 were analyzed by the USGS National Water Quality Laboratory in Denver, Colorado, according to USGS published methods, which are available at http://nwql.usgs.gov/rpt.shtml?pubs (U.S. Geological Survey, 2016b).

Additional surface water samples were collected in October 2011, July 2013, and October 2014 for the following elemental analyses: arsenic (As), boron (B), cadmium, chromium (Cr), copper (Cu), fluoride, iron (Fe), mercury (Hg), manganese (Mn), lead, selenium (Se), and zinc (tables 1 and 2). October 2011, October 2013, and October 2014 samples were also analyzed for the major ions calcium, chlorine, magnesium, potassium (K), sodium, and sulfate so the ions could be included on Stiff diagrams. Water samples collected in 2011 were prepared and preserved for analysis by Reclamation's LC Regional Laboratory in Boulder City, Nevada, according to standard operating procedures (Eaton and others, 2005). All water samples collected in 2013 and 2014 were preserved and shipped to the National Water Quality Laboratory for analysis according to their published methods, which are available at http://nwql.usgs.gov/rpt.shtml?pubs (U.S. Geological Survey, 2016b).

Long-Term Water Chemistry

Historically, Reclamation has collected quarterly or monthly water samples from the upstream side of the South Dike outlet gate structure using their standard operating procedures (Bureau of Reclamation, 2009). The samples were subsequently analyzed by Reclamation's LC Regional Laboratory for the following parameters: SC, TDS, pH, sodium, K, calcium, magnesium, carbonate, bicarbonate, alkalinity (as calcium carbonate), chlorine, sulfate, silicon dioxide, fluoride, NO_3+NO_2-N, nitrate, and hardness (as calcium carbonate) (app. 1). Data from late 1983 to April 2015 were provided by Reclamation (Janet Kirsch, written commun., 2015). Reclamation has not historically collected biological data on aquatic flora and fauna within Topock Marsh.

Sediment Chemistry

Sediment samples were collected in October 2011, July 2013, and October 2014 at each sampling station by hand using powder-free latex gloves. The samples were placed in labeled Ziploc plastic bags, kept on ice, and later refrigerated until analysis (tables 1 and 2). Sediment samples were analyzed by the Colorado State University's (CSU's) Soil, Water and Plant Testing Laboratory in Fort Collins, Colorado, according to standard procedures (Gee and Bauder, 1986; Workman and others, 1988; U.S. Department of Agriculture, 1996). Analyses included routine soil testing of pH; electrical conductivity; lime estimate; percentages of organic matter, sand, silt and clay; plant available nutrients (nitrate-nitrogen [NO_3-N], phosphorus, K, zinc, Fe, Mn, and Cu); and four elements of concern (As, Se, Hg, and hexavalent Cr).

Plant Chemistry

Plant samples were collected from each sampling station in July 2013 and October 2014 using ceramic knives and powder-free latex gloves. In addition, a replicate sample was collected at TP-6 in July 2013 and a sample was collected along the South Dike (TP-9) in October 2014. The goal was to test for the nutrient value and the chemical composition of the plants to see if the chemicals in the plants were at potentially toxic levels to wildlife. Submerged aquatic vegetation (SAV) was targeted because of its value as food to waterfowl. Each plant sample, which included above- and below-ground material, was placed in labeled Ziploc plastic bags, kept on ice, and then refrigerated until analysis (tables 1 and 2). Plant samples were analyzed by CSU's Soil, Water and Plant Testing Laboratory in Fort Collins, Colorado, according to standard procedures (U.S. Environmental Protection Agency, 1986b; Miller and Kotuby-Amacher, 1994). The analyses included routine testing for nitrogen, NO_3-N, calcium, magnesium, sodium, K, phosphorus, sulfur, Fe, Mn, Cu, zinc, B, molybdenum, aluminum, percent dry matter and four elements of concern (As, Se, Hg, and Cr). Owing to the scarcity of SAV in July 2013, all of the plants collected for that sampling period were emergent California bulrush (*Schoenoplectus californicus*). In October 2014, however, SAV was abundant, so four spiny naiad (*Najas marina*) samples and one Eurasian watermilfoil (*Myriophyllum spicatum*) sample were collected for chemical analyses because of their higher value to waterfowl. For consistency, we would have liked to have collected California bulrush as we did in July 2013 but, because of higher water depths, California bulrush was not sampled during October 2014. All October 2014 samples were analyzed for the same elements as the July 2013 samples with the exclusion of Cr. The Cr analysis was discontinued because of the low values measured in the 2013 samples and to reduce analyses costs.

Biological Characteristics—Protocol and Equipment

Aquatic Vegetation

SAV coverage within Topock Marsh was quantified by establishing transects that ran west to east in association with the sampling stations. Techniques were devised during our first sampling trip (July 2011) and all subsequent SAV transects were conducted with the assistance of AZFWCO or Havasu NWR staff.

A 6-m (20-ft) Jon boat powered by an outboard motor was used in surveying the transects, and a black and white underwater camera was used to detect plants when none could be seen from the water surface because of turbidity or water depth. The camera, hung off the side of the boat and held near the marsh floor by the cable, was turned 360 degrees at each sample point along each transect to look for vegetation, and the picture of the marsh floor was displayed on the video screen on the boat. When visual inspections were impossible to make from the boat or with the underwater camera, a weed rake was thrown from the boat 3 times and dragged along the marsh floor for approximately 10 seconds at random intervals (approximately every 31–61 m (102–200 ft) or as fast as data could be recorded before taking the next sample) at idle speed (speed that would not generate a wake, which is from 600 to 800 engine revolutions per minute) to spot check for any possible vegetation. Turbidity and water depths were measured at the same points along the transects during these surveys to provide information on the conditions to which the aquatic vegetation was being exposed. Coverage by species was estimated at each sample point as the proportion of live vegetation growing from an approximate 1-square meter (10.8-square foot) bottom area and was recorded as coverage ratings of 0, 1, 2, and 3, where 0 = no vegetation, 1 = <30 percent (low) vegetation coverage, 2 = 30–<70 percent (moderate) coverage, and 3 = 70–100 percent (high) coverage. Transects were evaluated during September and October 2011, January/February 2012, July and October 2013, and October 2014 (table 2).

The four coverage ratings for SAV were plotted in relation to the turbidity measured at 0.2 m (7.9 in.) below the water surface ("surface turbidity") and the water column depth at each observation point along the transects. We used October data (when SAV was at maximum levels) to examine the relationship between SAV coverage ratings and surface turbidity and water depth, using one-way analysis of variance (ANOVA) analysis. Tukey's Honest Significant Difference Test was used to examine pairwise comparisons (Neter and others, 1996) and Akaike's Information Criteria (Sakamoto and others, 1986) were examined to determine the best model.

The emergent aquatic vegetation coverage in Topock Marsh was quantified in 2014 as part of the FWS Desert Landscape Conservation Cooperative project and referred to as Tier 2 in that proposal. A total of 6,683 global positioning system (GPS) points capturing the various land cover classes located primarily along the marsh edge were collected and recorded using georeferenced survey-grade Trimble GPS units. Vegetation composition and respective canopy cover were estimated for the immediate area surrounding each point (approximately a 2-m [6.6 ft] radius circle around the center), including open water and SAV-covered areas. Those data collected along with the bathymetry data (Tier 3) in December 2013 and April 2014 were used with World View-2 imaging, captured on July 22, 2014, and October 11, 2014, to create a land-cover classification model of the vegetation of Topock Marsh.

The specific vegetation composition data recorded on the Trimble GPS units were used to "train" a model to determine land area covered by specific plant species. The development of the model by students and staff at CSU's Resource Ecology Laboratory to predict the area covered by emergent vegetation is described in detail in their report (Young and others, 2015) and is discussed thoroughly in the Tier 2 section of the final DSS report (Holmquist-Johnson and others, 2016). Because we did not expect the World View-2 imaging to "see" into the water, our goal initially was to determine only those areas covered by emergent vegetation. However, when evidence of what looked like SAV was seen in the images over open water, the CSU team also attempted to model the SAV-covered areas. In addition to the data collected for the modelling effort, field observations of the aquatic vegetation were recorded to document other conditions that were considered to be ecologically noteworthy.

Phytoplankton and Zooplankton

Phytoplankton samples were collected at each sampling station during most sampling trips (tables 1 and 2). The entire water column was sampled (see the "Chlorophyll *a*, Nutrients, Major Ions, and Trace Elements" section of this report for information on collection techniques). Unfiltered phytoplankton samples were preserved with a 2 percent Lugol's solution and identified and enumerated by BSA Environmental Services, Inc. (Beachwood, Ohio). Phytoplankton data for each taxonomic group were reported as total biovolume in cubic micrometers per milliliter (μm^3/mL) and cell density in number of cells per milliliter. Biovolume was estimated using the formula for solid geometric shapes that most closely match the cell shape (Hillebrand and others, 1999). If possible, biovolume calculations were based on measurements of 10 organisms per taxon for each sample.

Zooplankton samples were collected at each sampling station during most sampling trips (tables 1 and 2). Three vertical tows with a standard zooplankton net (20-cm [0.7-ft] mouth, 80-cm [2.6-ft] length, and 64-µm [0.003 in.] mesh) were collected as one sample and preserved using at least a 2 percent Lugol's solution. For later identification and enumeration, 3–4 percent Lugol's solution was added depending on the amount of detritus in the sample, as requested by Dr. John Beaver (John Beaver, written commun., 2011). Vertical tows were up to 2 m (6.6 ft) in length, depending on the depth at each sample station.

Zooplankton were identified, and density and biomass estimates made, by BSA Environmental Services, Inc.; biomass calculations were based on established length/width relationships of zooplankton anatomy (Dumont and others, 1975; Lawrence and others, 1987). Biomass was computed for the appropriate number of individuals for each sample location and the arithmetic mean biomass was multiplied by the number of species to produce a species biomass for each sample (McCauley, 1984). Zooplankton data for each taxonomic group were reported as biomass (micrograms dry weight/liter [pounds per gallon]) and density (number of individuals/liter [number of individuals/gallon]).

Small Biota Sampling

Small biota included the aquatic macroinvertebrates and crayfish that were sampled from shore near each sampling station as shown in tables 1 and 2. Aquatic macroinvertebrates were sampled from the 8.8 m (29 ft) Clark Boat using standard methods (Nelson and others, 2000). For consistency, we sought shoreline locations with a patch of spiny naiad, which is the most abundant SAV species and, therefore, good habitat for aquatic macroinvertebrates. A D-frame sweep net (700-µm [0.028-in.] mesh) was swept along the length of the boat perpendicular to the shoreline; the bottom of the net lightly scraped but did not dig into the bottom substrate. Although attempting to sample the same volume of habitat at each sample location, the goal was not to detect all macroinvertebrate taxa within Topock Marsh but to obtain comparable representative samples of common aquatic macroinvertebrates living within the spiny naiad and along the bottom surface. Three net sweeps were conducted at each location on each sampling date. Sample locations were recorded using a GPS. Mean water depth at each location was estimated from three depths taken equidistant along the sweep with a meter stick. The macroinvertebrates were either sorted in the field or the samples were preserved with ethanol for sorting in the laboratory. Macroinvertebrates were primarily identified to genus, although some Odonata and Oligochaeta were identified to family and some Diptera were identified to subfamily. Identification was done under contract by Richard Durfee, a macroinvertebrate biologist of Hamilton, Montana. Data were reported as the sum of organisms collected at each sample location and date.

Fish Sampling

Annual Gill Net Surveys Conducted by the Arizona Game and Fish Department

The Arizona Game and Fish Department's (AGFD's) Kingman office conducted gill net surveys at Topock Marsh each February from 2010 to 2015 at 10 locations within the marsh. AGFD biologists used experimental gill nets that are 45.7-m (150-ft) long, and consist of six 7.6-m (25 ft) panels with different mesh sizes ranging from 12 to 76 millimeters (0.5 to 3.0 in.) to capture different species and size classes of fish. AGFD set the nets so that the mesh size closest to shore varied. GPS locations were recorded at each net location. For 2–3 consecutive days, nets were typically deployed in the late afternoon and retrieved the following morning, and because all deployment and retrieval times were recorded, the total number of hours that each net was deployed was calculated. All captured fish were identified, measured, and weighed before release and, after 2010, razorback suckers were scanned for pit-tags. AGFD provided the fish survey reports for 2010, 2011, 2012, 2013, 2014, and 2015 (app. 2). The survey protocol and personnel were the same each year, therefore, results from these February fish surveys were used to evaluate changes in fish populations between sampling years. In the reports, AGFD used the estimate of catch per unit effort as a surrogate measure of fish abundance. For gill nets, catch per unit effort was calculated as the number of fish captured per hour per net.

Results

Water-Quality Characteristics

Physicochemistry

Water temperatures were measured instantaneously within a vertical profile using a Hydrolab Quanta® (fig. 4) and measured hourly at a fixed location with Hydrolab MiniSondes® (fig. 5) that were deployed for periods lasting from 2.5 to 9 days. Water temperatures were obtained at each of the 4 sampling stations on 11 sampling dates and at 2 stations in December 2013. Maximum water temperatures reached 33.2 °C (91.8 °F) just under the water surface at TP-2 during July 2011, and 35.8 °C (96.4°F) at TP-3 during July 2013 (figs. 4 and 5). The lowest water temperatures measured were 9.5 °C (49.1 °F) at TP-2 and TP-3 in February 2012 and 5.2 °C (41.4 °F) at TP-3 in December 2013 (figs. 4 and 5). Measurements at TP-3, the shallowest sampling station (1.2 m [3.9 ft] deep or less), contained the widest temperature extremes at a single location (fig. 4*Ba*). TP-2, the deepest sampling station (2.9 m [9.5 ft] deep at its deepest during June 2013 and April 2014), displayed the greatest temperature change with depth; that is, 30.2 °C (86.4°F) just under the water surface to 24.5 °C (76.1°F) at the depth of 2.3 m (7.5 ft) on September 21, 2011, (fig. 4*Ab*) and 29.5 °C (85.1 °F) just under the water surface to 21.3 °C (70.3 °F) at the depth of 2.9 m (9.5 ft) on June 12, 2013, (fig. 4*Bb*). In contrast, during June 2013, Colorado River water temperatures just downstream of the Needles Bridge and approximately 4 km (2.5 mi) upstream of the Fire Break Canal Water Diversion Structure, averaged 20.9 °C (69.6 °F) (Scott O'Meara, Bureau of Reclamation, unpub. data, 2014). During the cooler months, there was not as large a temperature difference between the marsh and the river (fig. 2*A*). However, temperatures at other locations in the marsh remained fairly constant from surface to bottom (that is, the entire water column) through the seasons, with the exception of TP-8 in July 2013 where there were notable temperature differences between the surface and at 0.5 m (1.6 ft) depth (fig. 4*Bd*).

Following the 260-day period of no flow through the Inlet Canal in 2011, SC values during the first sampling trip in July 2011 were higher at TP-3 and TP-2 with 2,470 µS/cm (1,583 parts per million [ppm]) and 2,600 µS/cm (1,667 ppm), respectively, than at TP-6 with 1,970 µS/cm (1,263 ppm), and the SC at TP-8 was even lower at 1,158 µS/cm (742 ppm) (figs. 6*A* and 7*A* and table 4). During this time, inflow was still coming from the Farm Ditch Canal (see fig. 2*A*). In September 2011, following a two-month period of fairly constant but relatively low flows from the Inlet Canal (fig. 2*A*), SC dropped to 995 µS/cm (638 ppm) at TP-3 and rose to 1,550 µS/cm (994 ppm) at TP-8 (table 4). Interestingly, SC at TP-2 was 1,412 µS/cm (905 ppm) just under the water surface but decreased to 1,132 µS/cm (726 ppm) at the 2.3 m (7.5 ft) water depth. During that time, operational testing of the Fire Break Canal temporarily brought Colorado River water directly into the marsh at TP-2 (fig. 6*Ab*), thus lowering SC and water temperature with depth. By October 2011, after an average daily flow from the Inlet Canal of 0.286 cubic meters per second (m^3/s), which is equivalent to 10.1 cubic feet per second (ft^3/s), and a flow rate of 0.139 m^3/s (4.9 ft^3/s) from the Farm Ditch Canal (fig. 2*A*), SC increased at TP-6 and TP-8 (figs. 6*Ac*, 6*Ad*, and 7*A*), and the trend of higher SCs moving downstream continued into March 2012, as SC at TP-8 increased to 2,390 µS/cm (1,532 ppm) (fig. 6*Ad* and table 4).

Compared to the July 2011–March 2012 low water sampling period, SC did not vary as much seasonally during 2013–14. Instead, the most downstream sampling station, TP-8, consistently experienced the highest SC values, ranging from 1,757 µS/cm (1,126 ppm) to 2,115 µS/cm (1,356 ppm) (figs. 6*Bd* and 7*B*). TP-2, adjacent to where inflow from the Colorado River enters the marsh, typically experienced the lowest SC values, ranging from 900 to 1,599 µS/cm (577 to 1,025 ppm), particularly during the growing season when inflows were high and the cool, fresher river water, with an average temperature of 20.5 °C (68.9 °F) and an SC of 895.5 µS/cm (574 ppm) (Scott O'Meara, written commun., 2014), plunged to the deeper spots thus lowering the SC at those depths (fig. 6*Bb*). The exception was during December 2013 when there was virtually no flow into the marsh from any of the inlets for 29 days (fig. 2*A*). Interestingly, at that time, TP-3, the most upstream station, had lower SC values than TP-2. In February 2014, the marsh was at its lowest elevation of the year (fig. 2*B*) because of very little inflow and SC increased throughout the marsh. However, by the April 2014 sampling trip, SC values decreased again following higher inflows that began in mid-March. TP-3 had the second lowest SC values during the April 2014 sampling trip. At the beginning of the September 2014 sampling trip, TP-3 had higher SC values than TP-6. However, as time went on, SC decreased at TP-3 and increased at TP-6 so that by October 2, 2014, at 1600 hours, TP-6 was slightly higher than TP-3 and remained higher for the rest of the sampling trip. (fig. 7*B*).

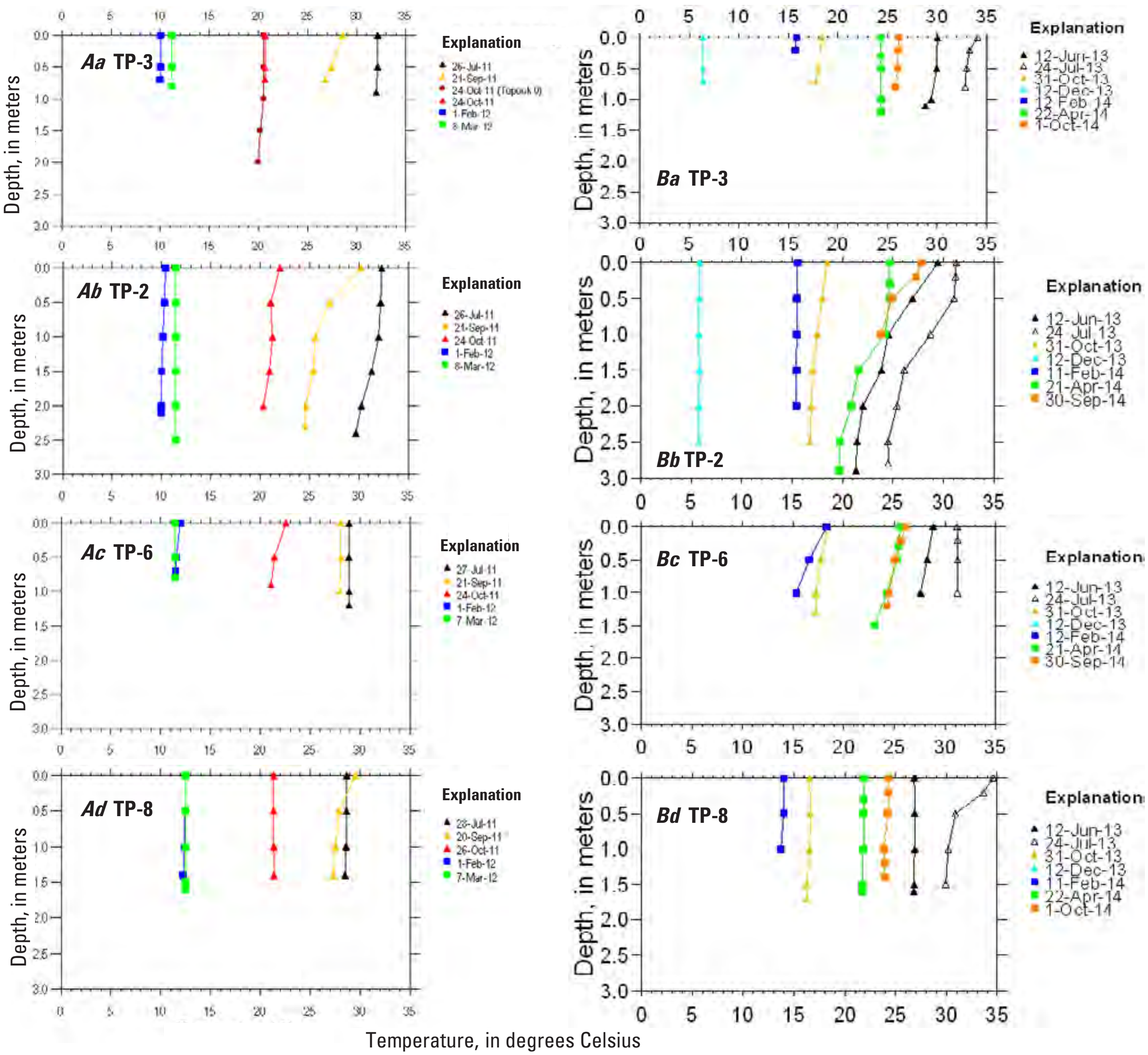

Figure 4. Depth profiles of water temperatures in Topock Marsh during 2011 and 2012 (*A*, charts on left) and 2013 and 2014 (*B*, charts on right) at sampling stations TP-3, TP-2, TP-6, and TP-8. Stations are displayed in upstream to downstream order, top to bottom, but numbering is not sequential. Colors represent seasons (blue = winter, green = spring, black = summer, yellow and red = fall) and symbols represent year (● or ▲ = 2011 and 2013, ■ = 2012 and 2014).

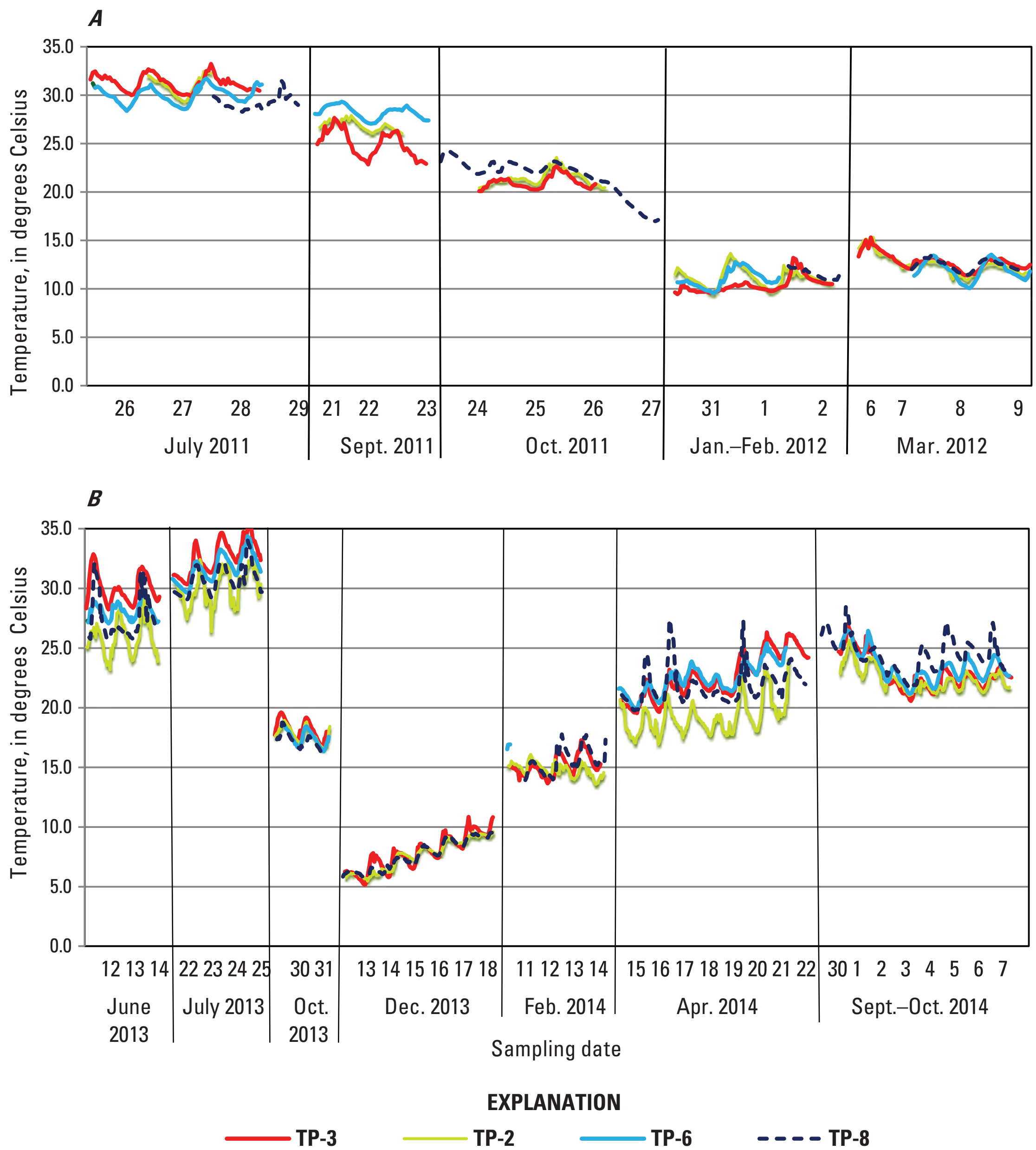

Figure 5. Diurnal temperatures in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 during site visits from July 2011 to March 2012 (*A*) and from June 2013 to September/October 2014 (*B*). Stations are displayed in upstream to downstream order, but numbering is not sequential.

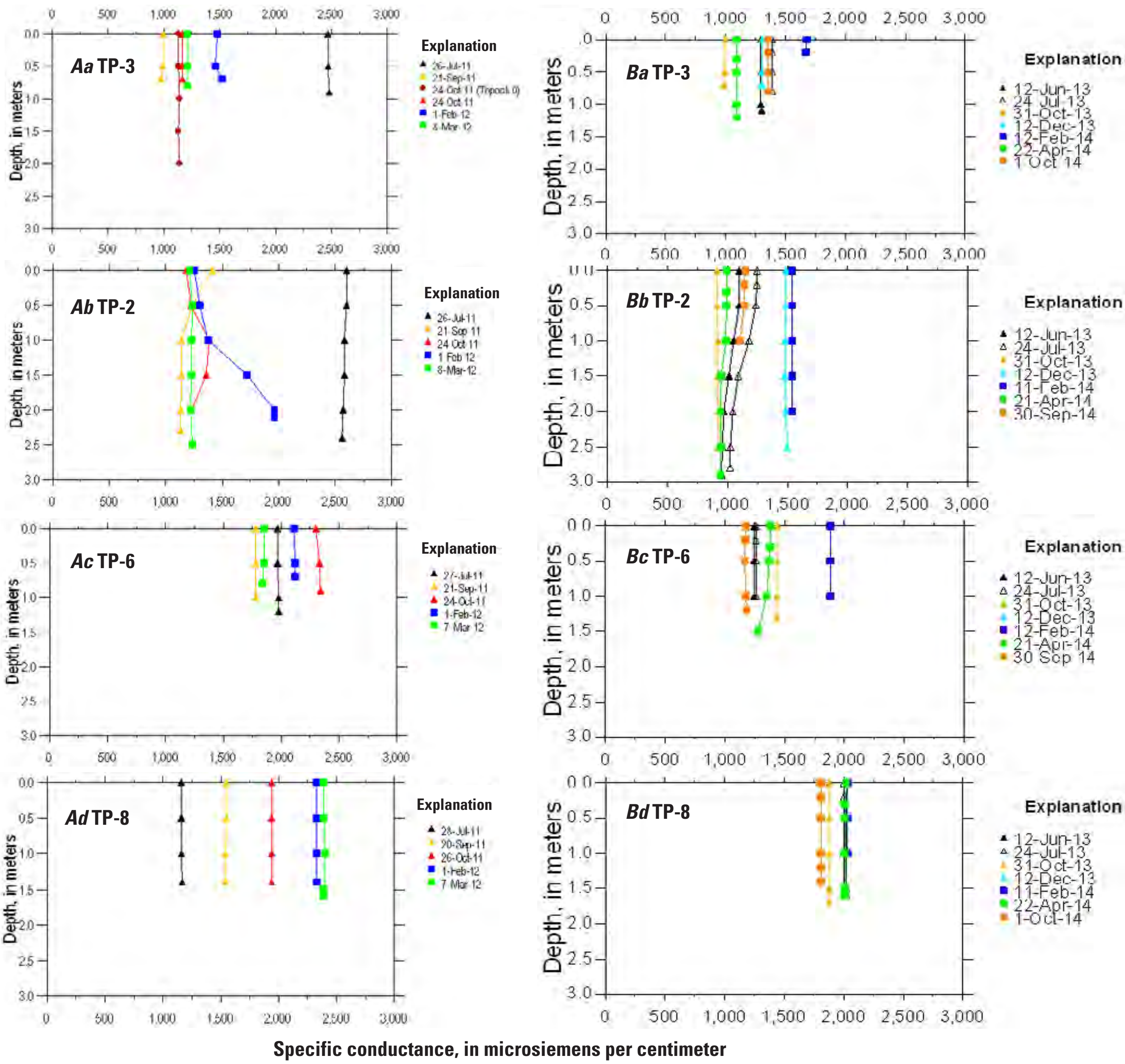

Figure 6. Depth profiles of specific conductance in Topock Marsh during 2011 and 2012 (*A*, charts on left) and 2013 and 2014 (*B*, charts on right) at sampling stations TP-3, TP-2, TP-6, and TP-8. Stations are displayed in upstream to downstream order, top to bottom, but numbering is not sequential. Colors represent seasons (blue = winter, green = spring, black = summer, fall = yellow or red) and symbols represent year (● or ▲ = 2011 and 2013, ■ = 2012 and 2014).

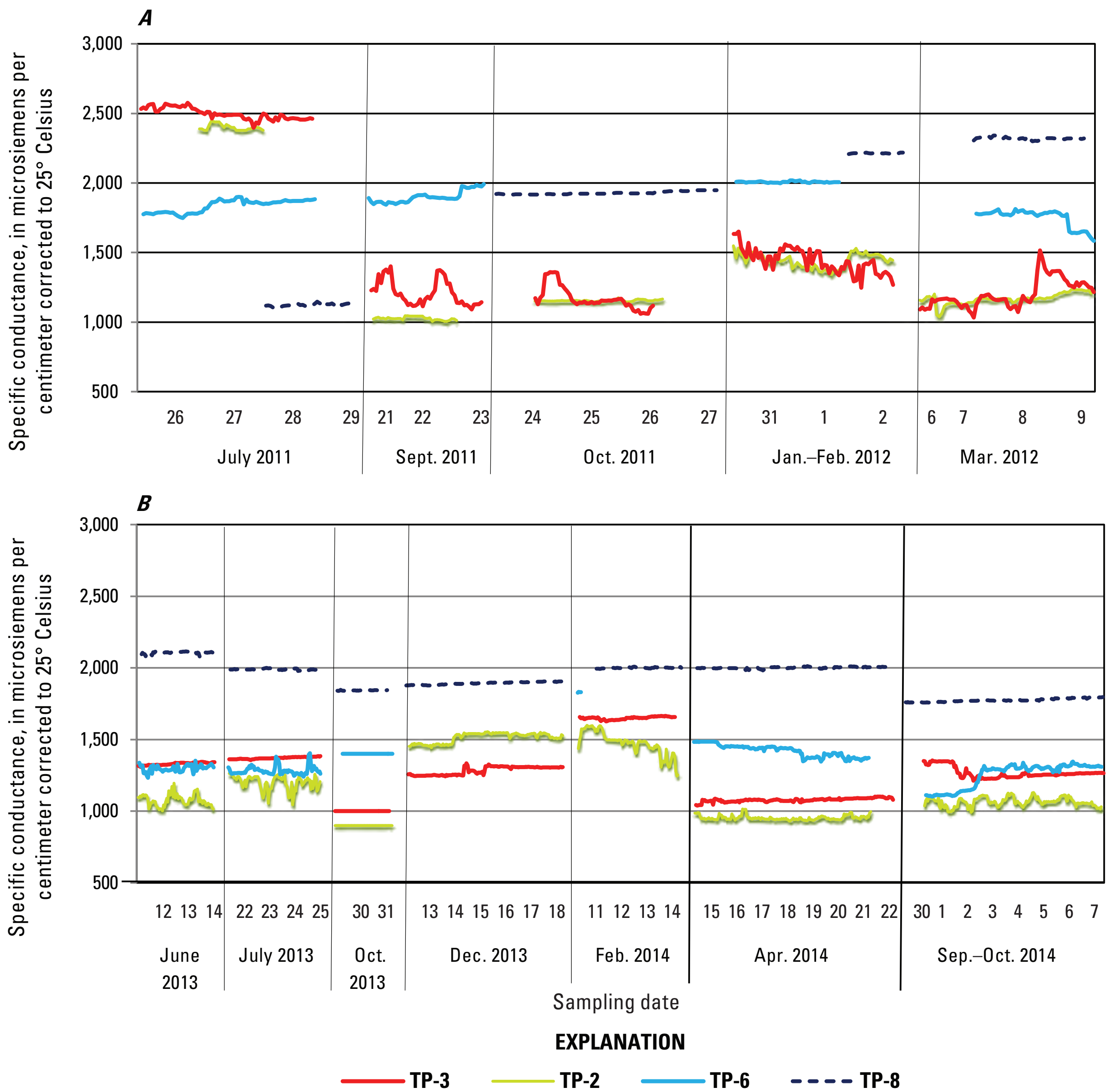

Figure 7. Diurnal specific conductance in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 during site visits from July 2011 to March 2012 (*A*) and June 2013 to September/October 2014 (*B*). Stations are displayed in upstream to downstream order, but numbering is not sequential.

Table 4. Concentrations of water-quality constituents collected from Topock Marsh in July, September, and October 2011; February and March 2012; June, July, and October 2013; and February, April, and September/October 2014.

[µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity unit; TSS, total suspended solids; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; P, phosphorus; NH_3, ammonia; Org-N, organic nitrogen; NH_3–N, ammonia-nitrogen; NO_3+NO_2–N, nitrate + nitrite nitrogen; N, nitrogen; TN, total nitrogen; %, percentage; TP, sampling station; ND, no data; NWQL, National Water Quality Laboratory; Calc., calculated; EPA, U.S. Environmental Protection Agency; ADEQ, Arizona Department of Environmental Quality]

Sample station[2]	Sample date	Surface values from Quanta		Laboratory analyses from surface samples[1]								
		Specific conductance µS/cm	Turbidity NTUs	TSS mg/L	Alkalinity as $CaCO_3$ mg/L	Total P mg/L	NH3 + Org-N mg/L	NH_3-N mg/L	Org-N mg/L	NO3+NO2-N mg/L	Total-N mg/L	Org-N/ TN %
TP-3	07/26/11	2,470	4.0		156.0	0.029	0.920	<0.007	0.916	<0.007	0.923	99.2
TP-2	07/26/11	2,600	68.9		161.6	0.036	0.992	0.019	0.973	<0.007	0.995	97.7
TP-6	07/27/11	1,970	39.3		147.2	0.026	0.629	<0.007	0.626	0.020	0.649	96.4
TP-8	07/28/11	1,158	53.0		144.8	0.038	0.654	<0.007	0.651	0.010	0.664	98.0
TP-3	09/21/11	995	58.4		99.2	0.053	0.323	<0.004	0.321	0.015	0.338	95.0
TP-2	09/21/11	1,412	51.4		114.4	0.053	0.540	<0.004	0.538	<0.007	0.543	99.0
TP-6	09/21/11	1,780	19.9		54.4	0.049	0.611	<0.004	0.609	<0.007	0.614	99.1
TP-8	09/20/11	1,550	30.5		93.6	0.055	0.935	<0.004	0.933	<0.007	0.938	99.4
TP-3	10/25/11	1,165	60.3		112.8	0.026		ND		ND	0.388	
TP-2	10/25/11	1,183	45.0		86.4	0.025		ND		ND	0.483	
TP-6	10/25/11	2,300	37.4		48.8	0.025		ND		ND	0.719	
TP-8	10/23/11	1,940	35.8		72.0	0.075		ND		ND	1.050	
2011 mean		**1710**	**42.0**		**107.6**	**0.041**	**0.700**	**0.019**	**0.696**	**0.015**	**0.692**	**98.0**
TP-3	02/01/12	1,478	72.6		148.0	0.040	0.421	0.030	0.392	0.193	0.614	63.8
TP-2	02/01/12	1,253	13.2		144.0	0.014	0.268	<0.010	0.263	0.345	0.613	42.9
TP-6	02/01/12	2,110	49.8		163.0	0.043	0.716	0.040	0.676	0.054	0.770	87.8
TP-8	02/01/12	2,330	81.1		158.0	0.087	1.320	0.024	1.296	0.010	1.330	97.4
TP-3	03/08/12	1,209	87.4		140.0	0.039	0.360	0.034	0.326	0.256	0.616	53.0
TP-2	03/08/12	1,210	51.8		142.0	0.037	0.371	0.025	0.346	0.284	0.655	52.9
TP-6	03/08/12	1,850	63.1		150.0	0.051	0.645	0.034	0.611	0.124	0.769	79.5
TP-8	03/09/12	2,390	70.3		164.0	0.081	1.080	0.011	1.070	0.110	1.190	89.9
2012 mean		**1729**	**61.2**		**151.1**	**0.049**	**0.648**	**0.028**	**0.622**	**0.172**	**0.820**	**70.9**
2011–2012 study average		**1718**	**49.7**		**125.0**	**0.044**	**0.674**	**0.027**	**0.659**	**0.129**	**0.743**	**84.4**
TP-3	06/13/13	1,311	58.8	16	179	0.034	0.49	0.01	0.47	0.00	0.464	96.8
TP-2	06/13/13	1,140	66.8	<15	164	0.023	0.41	<0.01	0.40	0.00	0.408	98.0
TP-6	06/13/13	1,291	19.5	<15	173	0.026	0.52	<0.01	0.52	0.00	0.483	99.0
TP-8	06/13/13	2,030	88.2	40	181	0.085	1.18	0.02	1.16	0.00	1.170	99.4
TP-3	07/24/13	1,389	18	ND	ND	0.027	0.51	0.01	0.49	0.00	0.495	99.8
TP-2	07/24/13	1,244	11.8	ND	ND	0.031	0.49	0.01	0.48	0.01	0.500	96.5
TP-6	07/24/13	1,259	17.7	ND	ND	0.027	0.59	<0.01	0.59	0.00	0.562	99.1
TP-8	07/23/13	2,000	26.5	ND	ND	0.066	1.31	<0.01	1.31	0.10	1.407	92.8
TP-3	10/31/13	1,000	11.3	<15	86.6	0.015	0.26	<0.01	0.26	0.02	0.275	92.7
TP-2	10/31/13	911	7.8	<15	130.0	0.008	0.205	<0.01	0.20	0.22	0.427	46.8

Table 4. Concentrations of water-quality constituents collected from Topock Marsh in July, September, and October 2011; February and March 2012; June, July, and October 2013; and February, April, and September/October 2014.—Continued

[µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity unit; TSS, total suspended solids; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; P, phosphorus; NH_3, ammonia; Org-N, organic nitrogen; NH_3–N, ammonia-nitrogen; NO_3+NO_2–N, nitrate + nitrite nitrogen; N, nitrogen; TN, total nitrogen; %, percentage; TP, sampling station; ND, no data; NWQL, National Water Quality Laboratory; Calc., calculated; EPA, U.S. Environmental Protection Agency; ADEQ, Arizona Department of Environmental Quality]

Sample station[2]	Sample date	Surface values from Quanta: Specific conductance µS/cm	Surface values from Quanta: Turbidity NTUs	Laboratory analyses from surface samples[1]: TSS mg/L	Alkalinity as $CaCO_3$ mg/L	Total P mg/L	NH3 + Org-N mg/L	NH_3-N mg/L	Org-N mg/L	NO3+NO2-N mg/L	Total-N mg/L	Org-N/TN %
TP-6a	10/31/13	1,440	11.2	<15	110.0	0.017	0.499	<0.01	0.49	0.01	0.508	97.2
TP-6b	10/31/13	ND	ND	15	110.0	0.018	0.515	<0.01	0.51	0.00	0.480	99.0
TP-8	10/31/13	1,880	134	80	163.0	0.188	1.21	<0.01	1.21	0.20	1.410	85.5
2013 mean		**1,408**	**39.3**	**38**	**144.1**	**0.043**	**0.630**	**0.013**	**0.62**	**0.04**	**0.661**	**92.5**
TP-3	02/12/2014	1,675	50.3	24	178.0	0.053	0.695	0.060	0.635	0.031	0.726	87.5
TP-2	02/11/2014	1,540	56.8	29	146.0	0.063	0.787	0.025	0.762	0.067	0.854	89.2
TP-6	02/12/2014	1,880	38.7	14	191.0	0.047	0.858	0.039	0.819	<0.010	0.863	94.9
TP-8	02/11/2014	2,030	112.0	97	193.0	0.154	1.835	0.281	1.554	0.025	1.860	83.5
TP-3	04/19/2014	1,092	72.6	46	156.0	0.056	0.472	0.011	0.461	<0.010	0.477	96.7
TP-2	04/19/2014	993	34.6	<15	148.0	0.026	0.353	<0.010	0.348	0.168	0.521	66.8
TP-6	04/19/2014	1,379	33.6	16	169.0	0.033	0.599	0.017	0.582	0.011	0.598	97.3
TP-8	04/19/2014	2,020	140.0	84	192.0	0.171	1.502	0.058	1.444	0.021	1.470	98.2
TP-3	10/1/2014	1,353	73.7	34	150.0	0.057	0.609	0.017	0.592	0.015	0.624	94.9
TP-2	09/30/2014	1,149	41.5	<15	145.0	0.031	0.387	0.023	0.364	0.073	0.460	79.1
TP-6a	09/30/2014	1,174	11.4	<15	72.6	0.018	0.440	0.017	0.423	<0.010	0.445	95.1
TP-6b	09/30/2014	ND	ND	<15	78.2	0.023	0.453	0.015	0.438	<0.010	0.458	95.7
TP-8	10/1/2014	1,810	83.7	40	118.0	0.133	1.399	0.021	1.378	0.011	1.410	97.8
2014 mean minus TP-8			**45.9**									
2014 mean		**1,508**	**62.4**	**43**	**149.0**	**0.067**	**0.799**	**0.049**	**0.754**	**0.047**	**0.828**	**90.5**
2013–2014 study average		**1,458**	**50.9**	**41.2**	**147.0**	**0.055**	**0.715**	**0.040**	**0.688**	**0.045**	**0.744**	**91.5**
NWQL Laboratory Codes				169	2109	2333	1986, Calc.[3]	3116	Calculated[3,4]	Calc.[4], 3157	2756	Calculated
NWQL Analytical Method Identification Codes				I-3765-89	I-2030-89	EPA 365.1		I-2525-89,I-2522-90			I-4650-03	
NWQL minimum reporting level				15	4.6	0.004		0.01		0.01	0.05	
ADEQ numeric targets for nutrients[5]						0.115–0.140	1.3–1.6				1.6–1.8	

[1]All 2011 laboratory analyses were done by Reclamation's LC Regional Laboratory and all 2012, 2013, and 2014 laboratory analyses were done by the USGS NWQL. All samples, including the Quanta values, were taken at the sampling stations from just below the water's surface.

[2]Sampling stations are displayed in upstream to downstream order.

[3]2014 values for NH3-N + Org-N and Org-N are calculated using half of "less than" detection limits for analyzed parameters. Formulas to calculate nitrogen forms follow those provided by Bales and others, 2001.

[4]2013 values for Org-N and NO3+NO2-N were calculated using half of "less than" detection limits for analyzed parameters. Formulas to calculate nitrogen forms follow those provided by Bales and others, 2001.

[5]The standards recommended by the Arizona Department of Environmental Quality (ADEQ) are specific to warmwater lakes and reservoirs designated for aquatic and wildlife use. Ranges apply to peak season (April to October for warm water lakes).All criteria were obtained from ADEQ (2009).

Values in red are less than 80% organic nitrogen to total nitrogen.

Values for pH showed some seasonal change. In July 2011, pH was very similar between the sampling stations, hovering near 8.0 regardless of the time of day (figs. 8*A* and 9*A*). By September 2011, there was more variation between the upstream and the downstream sampling stations; pH values ranged between 8.1 and 8.4 at TP-3 and TP-2, and between 8.4 and 9.0 at TP-6 and TP-8. October 2011 values varied the most, with a low of 7.8 at TP-2 and a high of 9.1 at TP-6. In January/February 2012, pH values were fairly consistent among sampling stations and water depth, and in March 2012, pH was slightly higher at TP-6 and TP-8.

Comparing pH values during 2013–14, the mean values increased slightly from June and July 2013 to October 2013, varying from a low of 7.9 at TP-8 in June to 9.1 at TP-3 in October (figs. 8*B* and 9*B*). The larger daily pH fluctuations at TP-3 during October and December 2013; at TP-6 each October (2013 and 2014); and at TP-8 in June, July, and October 2013 and April and October 2014, were especially pronounced (fig. 9*B*). The opposite was true throughout the marsh in February 2014, when pH values had much smaller daily fluctuations. Otherwise, pH ranged from 7.6 to 9.1 throughout the study period.

Dissolved oxygen concentrations varied seasonally and tended to be inversely related to temperature (compare figure 4 to figure 10 and figure 5 to figure 11). These concentrations were measured in mg/L, which is equivalent to ppm. The DO concentration was well above the minimum threshold of 3.0 mg/L that is established as the one-day criteria for “other life stages” of warm water fish by the U.S. Environmental Protection Agency (1986a).

Figure 12 illustrates water surface turbidity measured at each sampling station during the sampling period, figure 13 illustrates the turbidity depth profiles at each sampling station, and the turbidity diurnal trends from 2013 and 2014 are illustrated on figure 14.

Turbidity readings at the 4 sampling stations averaged 47.2 NTUs in 2011 and 61.2 NTUs in 2012 (table 4). TP-6 generally had higher water clarity than the other sites in 2011, as indicated by its average lower turbidity values (32.2 NTUs, number [n] = 3) and higher Secchi depth readings (0.59 m [1.9 ft], n = 3). Average turbidities of the other sites were 61.8 NTUs at TP-3, 55.1 NTUs at TP-2, and 39.8 NTUs at TP-8. However, windy weather was common in early 2012, with measured wind gusts often up to 64.4 km/h (40 mi/h), peaking at 90.1 km/h (56 mi/h) and 66.0 km/h (41 mi/h) during the March 2012 sampling trip (fig. 3*B*). Turbidities measured during January/February 2012 and March 2012 sampling trips at TP-6 were 49.8 NTUs (Secchi = 0.41 m [1.3 ft]) and 63.1 NTUs (Secchi = 0.30 m [1.0 ft]), respectively (table 4). Also of note is that the phytoplankton technician recorded that the TP-6 water column samples from January/February 2012 and March 2012 contained “very heavy sediment,” whereas phytoplankton samples from other months contained no discernable sediment (BSA Environmental Services, Inc., written commun., 2012).

Turbidity averaged 39.3 NTUs across the 4 sampling stations through the 2013 field trips, and averaged 62.4 NTUs through the 2014 field trips (table 4). Secchi disk measurements across the 4 sampling stations averaged 0.63 m (2.1 ft) and 0.43 m (1.4 ft), respectively (fig. 13). Sampling station TP-6 had only slightly higher average water clarity compared to TP-2 and TP-3 (figs. 12, 13, and 14), but water clarity was considerably lower at TP-8 than the other sites from July 2013 to October 2014 (figs. 12, 13, and 14).

Chlorophyll *a*, Nutrients, Major Ions, and Trace Elements

Analyses of surface water samples included chlorophyll *a* concentrations, nutrients, ion chemistry, and trace elements. Figure 15 illustrates chlorophyll *a* concentrations by sampling station (*A*) and by sampling date (*B*) from July 2011 to October 2014. The lowest chlorophyll concentrations occurred during October 2013 at TP-3, TP-2, and TP-6 when water temperatures were lower [average 18.4 °C (65.1 °F)], water elevation was higher [138.64 m amsl (454.86 ft amsl), turbidity was lower (average 10.1 NTUs), and SAV was dense. The highest chlorophyll *a* concentrations were consistently measured at TP-8 throughout the study period, with the highest values of 45.7 and 48.2 micrograms per liter (3.8 and 4.0 pounds per gallon) observed in October 2013 and October 2014, respectively (fig. 15).

Nutrients were measured in mg/L, which is equivalent to ppm. For the entire 2011–12 low water sampling period, means for nutrients were 0.04 mg/L for TP, 0.74 mg/L for TN, 0.66 mg/L for Org-N, ≤0.03 mg/L for NH_3-N, and 0.13 mg/L for NO_3+NO_2-N (table 4). Similarly, for the 2013–14 high water sampling period, means for nutrients were 0.06 mg/L for TP, 0.74 mg/L for TN, 0.69 mg/L for Org-N, 0.04 mg/L for NH_3-N, and 0.04 mg/L for NO_3+NO_2-N (table 4).

TP-8 consistently had higher concentrations of TN and TP compared to the other sampling stations, except for July 2011 (fig. 16). Additionally, analyses showed that Org-N accounted for 80 percent or more of the TN in most of the water samples, with the exceptions of samples collected from TP-3 and TP-2 during February and March 2012 and TP-2 during October 2013 and April 2014 (table 4, numbers in red). During those times, the percentage of NO_3+NO_2-N increased (table 4). All nutrient concentrations were below the Arizona Department of Environmental Quality numeric targets (table 4).

The composition of major ions in water samples collected from Topock Marsh in September/October 2011, October 2013, and September/October 2014 are illustrated using Stiff diagrams (figs. 17–19). The illustrations reveal similar spatial patterns, with some minor differences. In 2011, when inflows had been restricted for months, the two upstream stations (TP-3 and TP-2) were markedly different in ionic composition and concentration from the two downstream stations (TP-6 and TP-8). The ionic concentrations of TP-6 and TP-8 clearly declined from 2011 to 2014 as inflows into the marsh increased. The ionic concentrations of TP-2 and TP-3 changed only slightly between the sampling periods and were markedly similar to the Colorado River water measured at a nearby station (see inset in figs. 18 and 19).

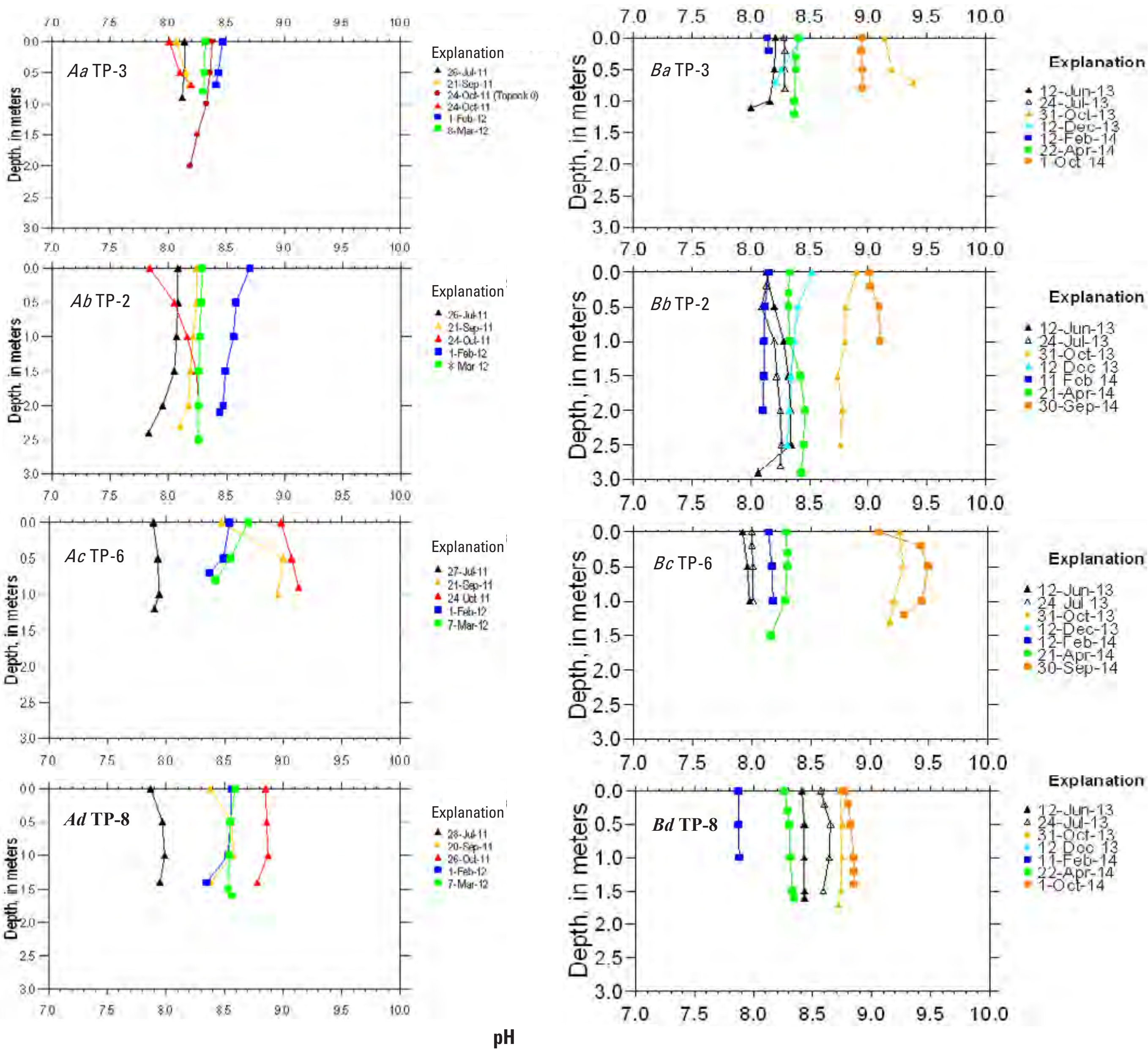

Figure 8. Depth profiles of pH in Topock Marsh during 2011and 2012 (*A*, charts on left) and 2013 and 2014 (*B*, charts on right) at sampling stations TP-3, TP-2, TP-6, and TP-8. Stations are displayed in upstream to downstream order, top to bottom, but numbering is not sequential. Colors represent season (blue = winter, green = spring, black = summer, yellow or red = fall) and symbols represent year (● or ▲ = 2011 and 2013, ■ = 2012 and 2014).

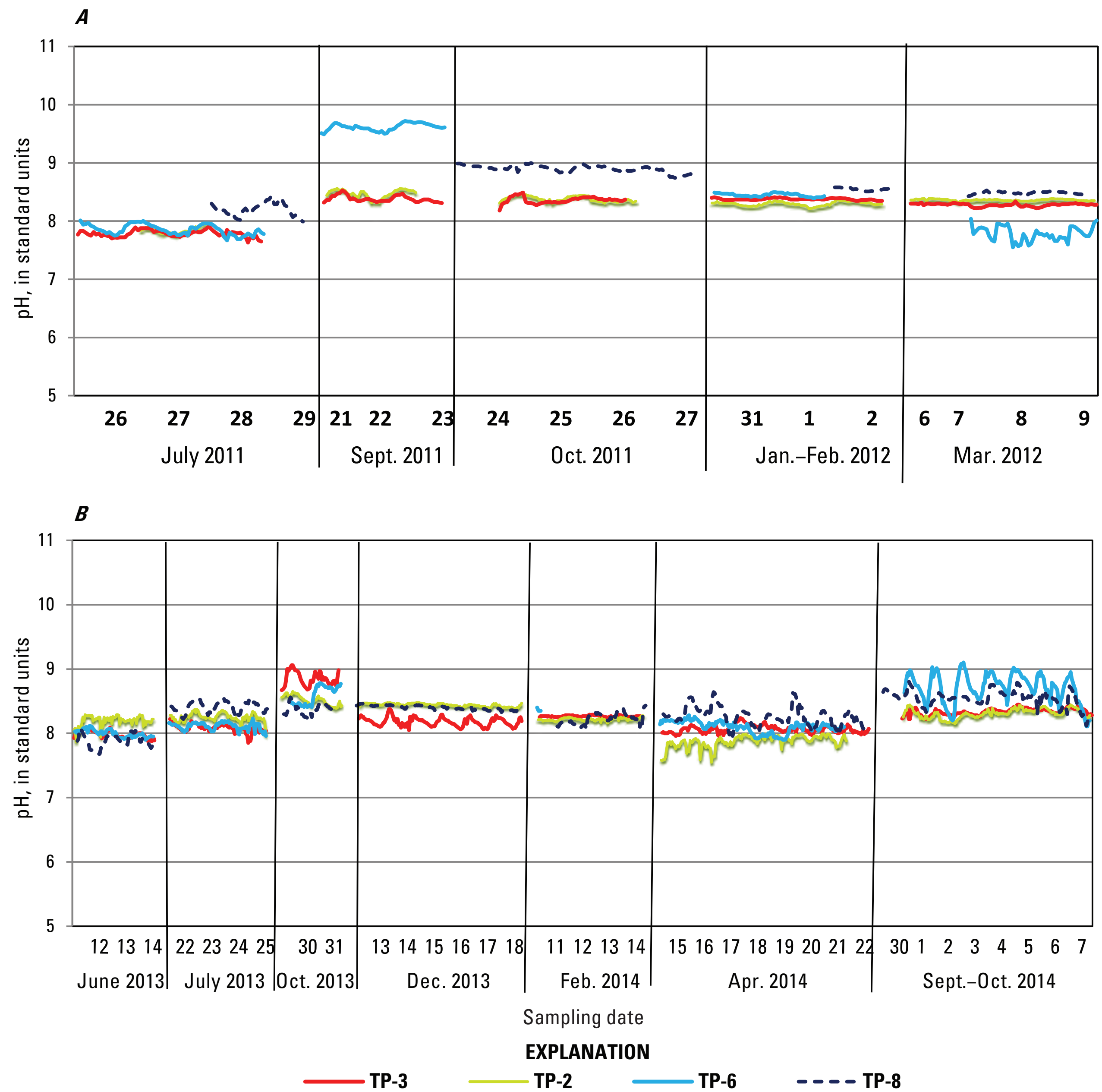

Figure 9. Diurnal pH in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 during site visits from July 2011 to March 2012 (*A*) and from June 2013 to September/October 2014 (*B*). Stations are displayed in upstream to downstream order, but numbering is not sequential.

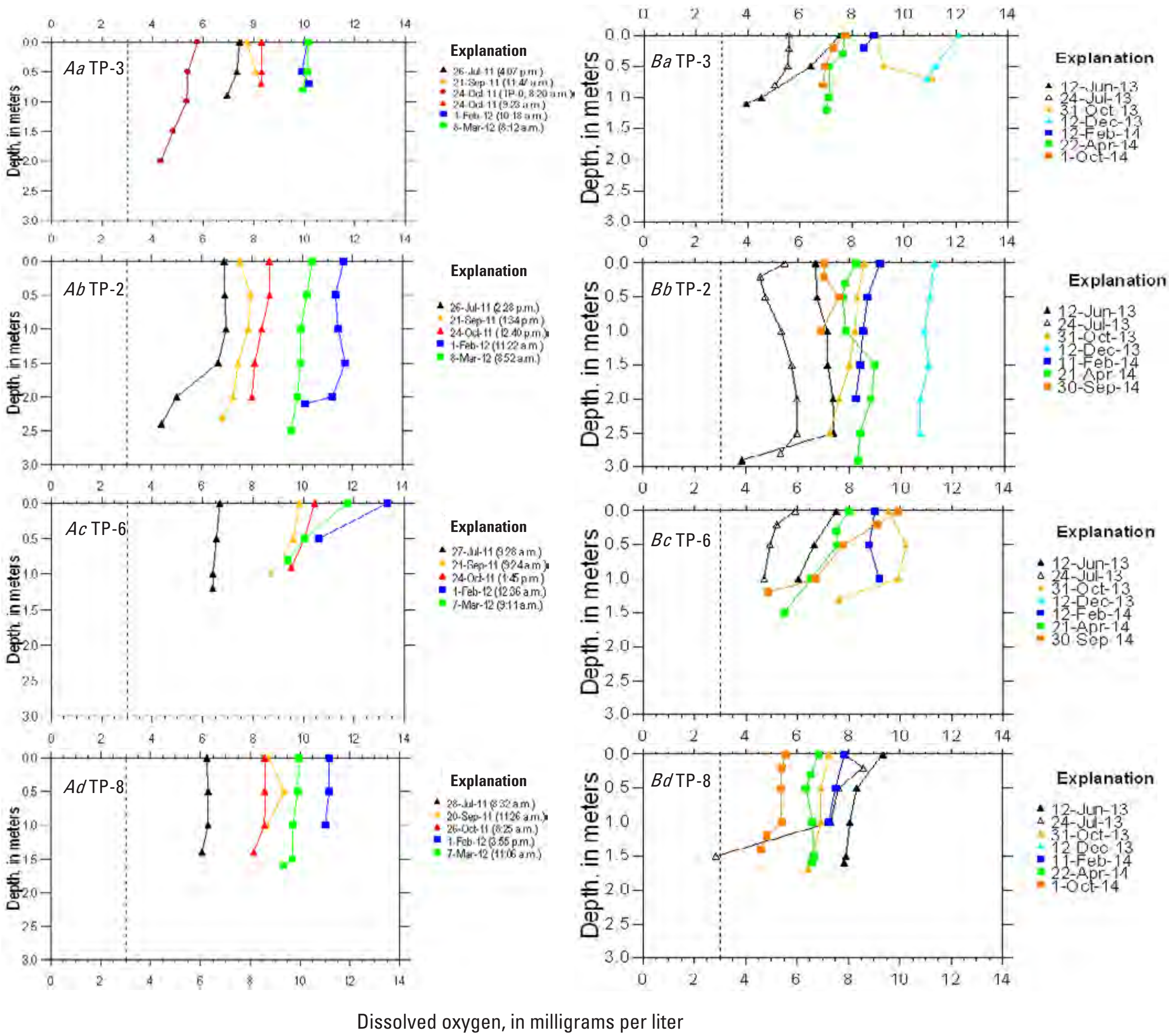

Figure 10. Depth profiles of dissolved oxygen in Topock Marsh during 2011 and 2012 (*A*, charts on left) and 2013 and 2014 (*B*, charts on right) at sampling stations TP-3, TP-2, TP-6, and TP-8. Stations are displayed in upstream to downstream order top to bottom, but numbering is not sequential. Colors represent season (blue = winter, green = spring, black = summer, yellow or red = fall) and symbols represent year (● or ▲ = 2011 and 2013, ■ = 2012 and 2014). The vertical dashed line at 3.0 milligrams per liter dissolved oxygen indicates the U.S. Environmental Protection Agency (EPA) 1-day minimum criteria for “other life stages” of warm water fish (EPA, 1986a).

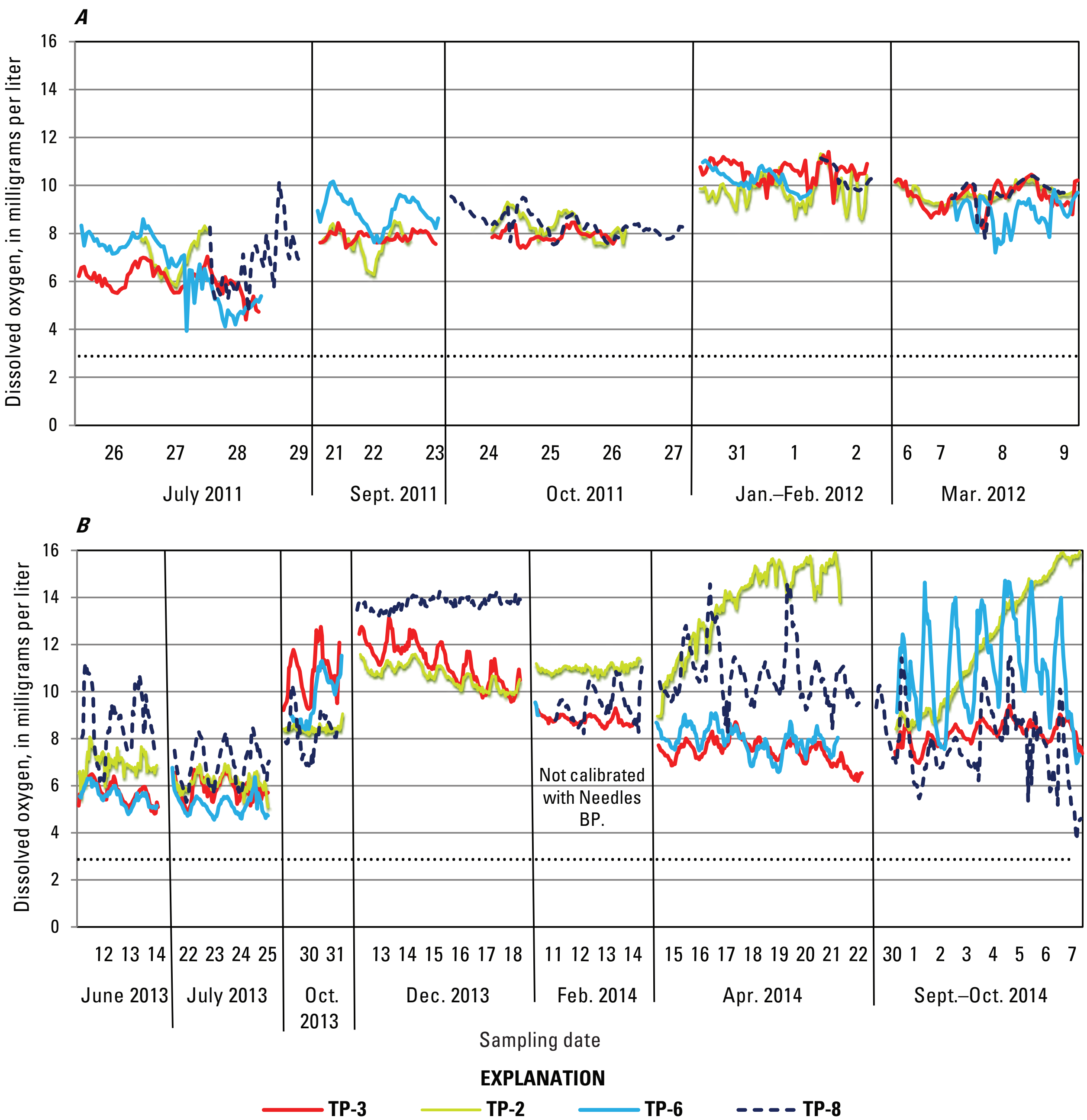

Figure 11. Diurnal dissolved oxygen in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 during site visits from July 2011 to March 2012 (*A*) and from June 2013 to September/October 2014 (*B*). Stations are displayed in upstream to downstream order, but numbering is not sequential. The dotted horizontal line illustrates the minimum threshold of 3.0 milligrams per liter established as the one-day criterion for "other life stages" of warm water fish by the U.S. Environmental Protection Agency (EPA). (EPA, 1986a).

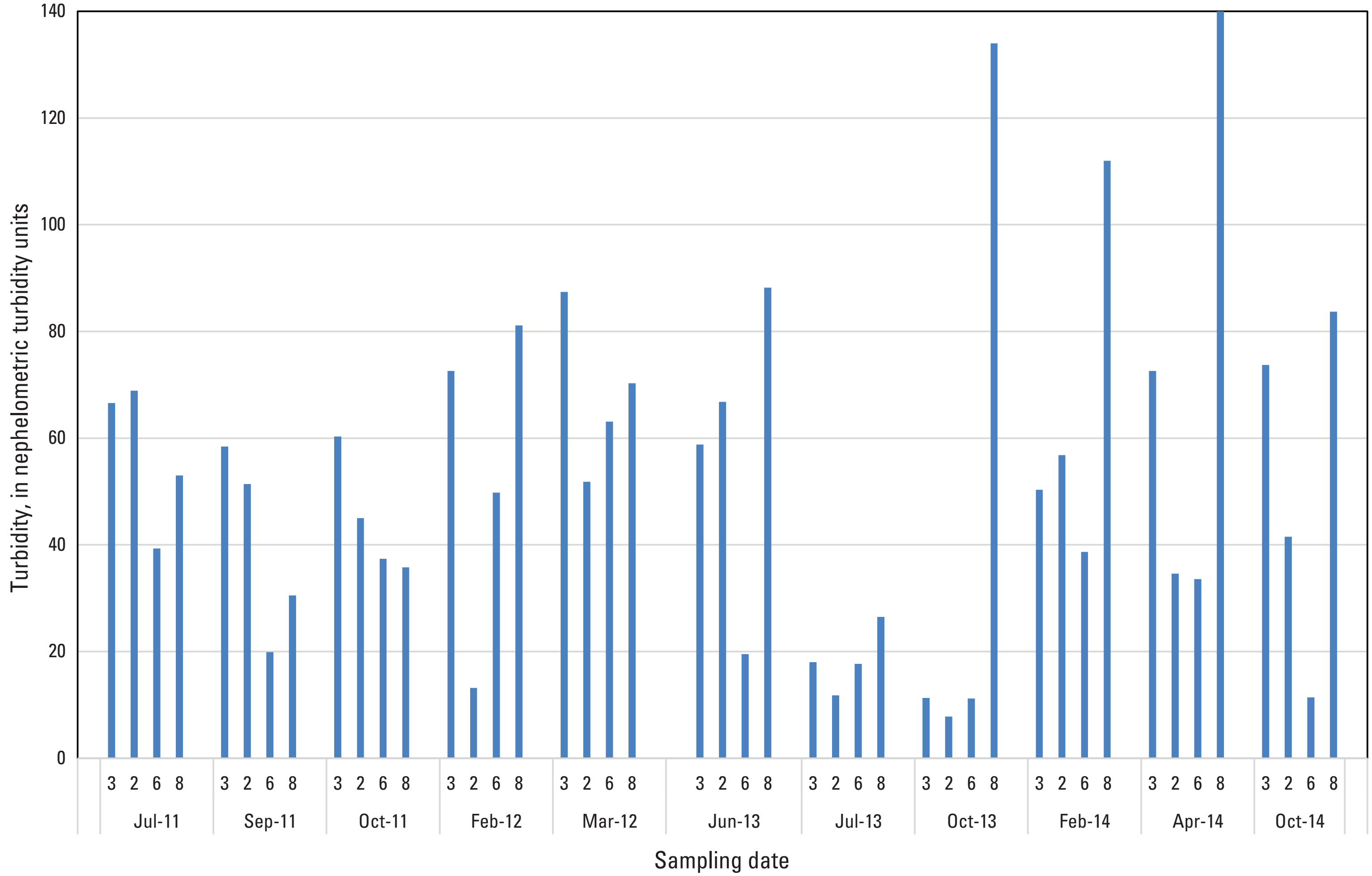

Figure 12. Surface water turbidity in Topock Marsh at sampling stations TP-3 (3), TP-2 (2), TP-6 (6), and TP-8 (8) from July 2011 to October 2014. Stations are displayed in upstream to downstream order, but numbering is not sequential.

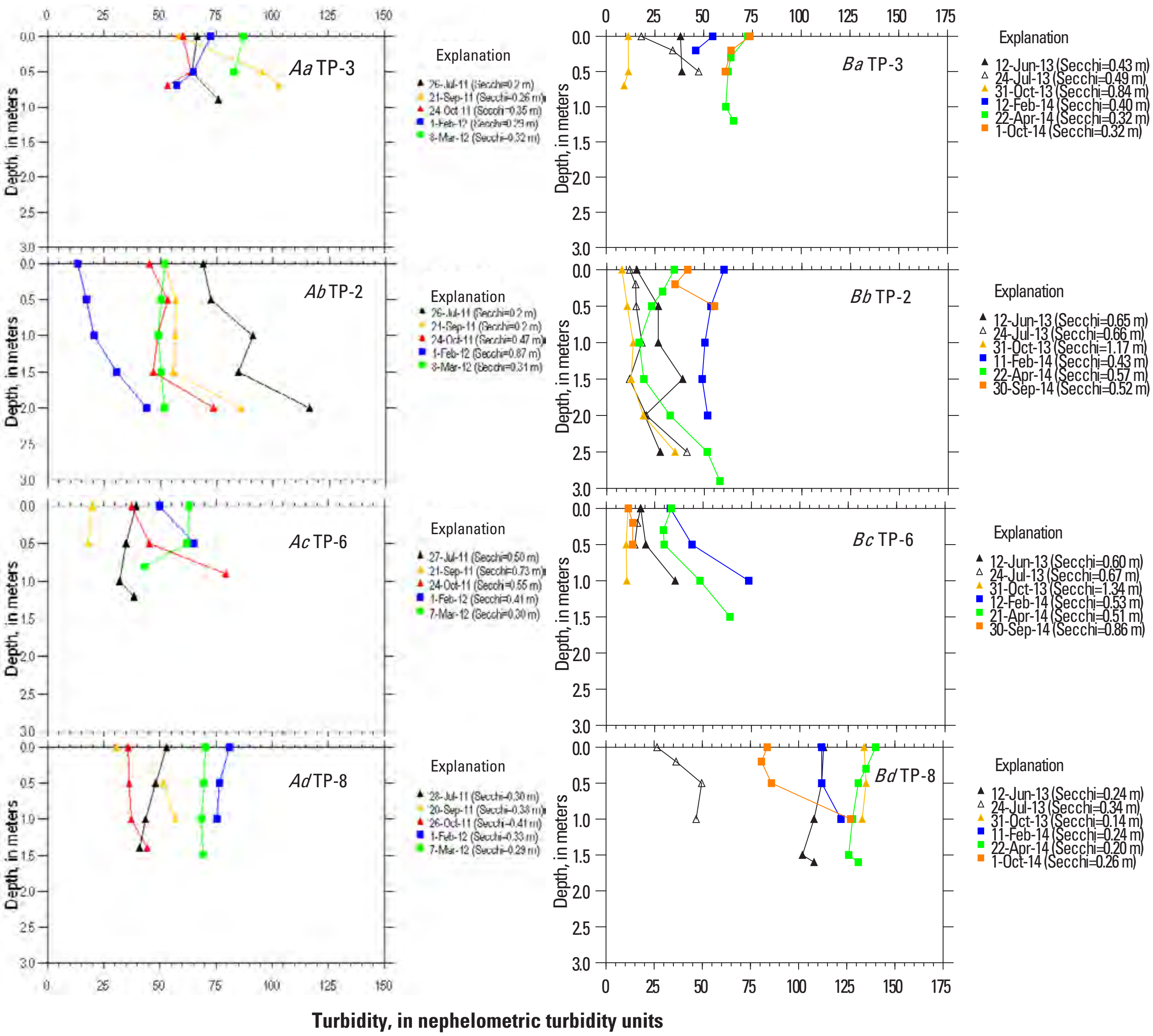

Figure 13. Depth profiles of turbidity and concurrent Secchi depths in Topock Marsh during 2011 and 2012 (*A*, charts on left) and 2013 and 2014 (*B*, charts on right) at sampling stations TP-3, TP-2, TP-6, and TP-8. Stations are displayed in upstream to downstream order, top to bottom, but numbering is not sequential. Colors represent season (blue = winter, green = spring, black = summer, yellow or red = fall) and symbols represent year (▲ = 2011 and 2013, ■ = 2012 and 2014).

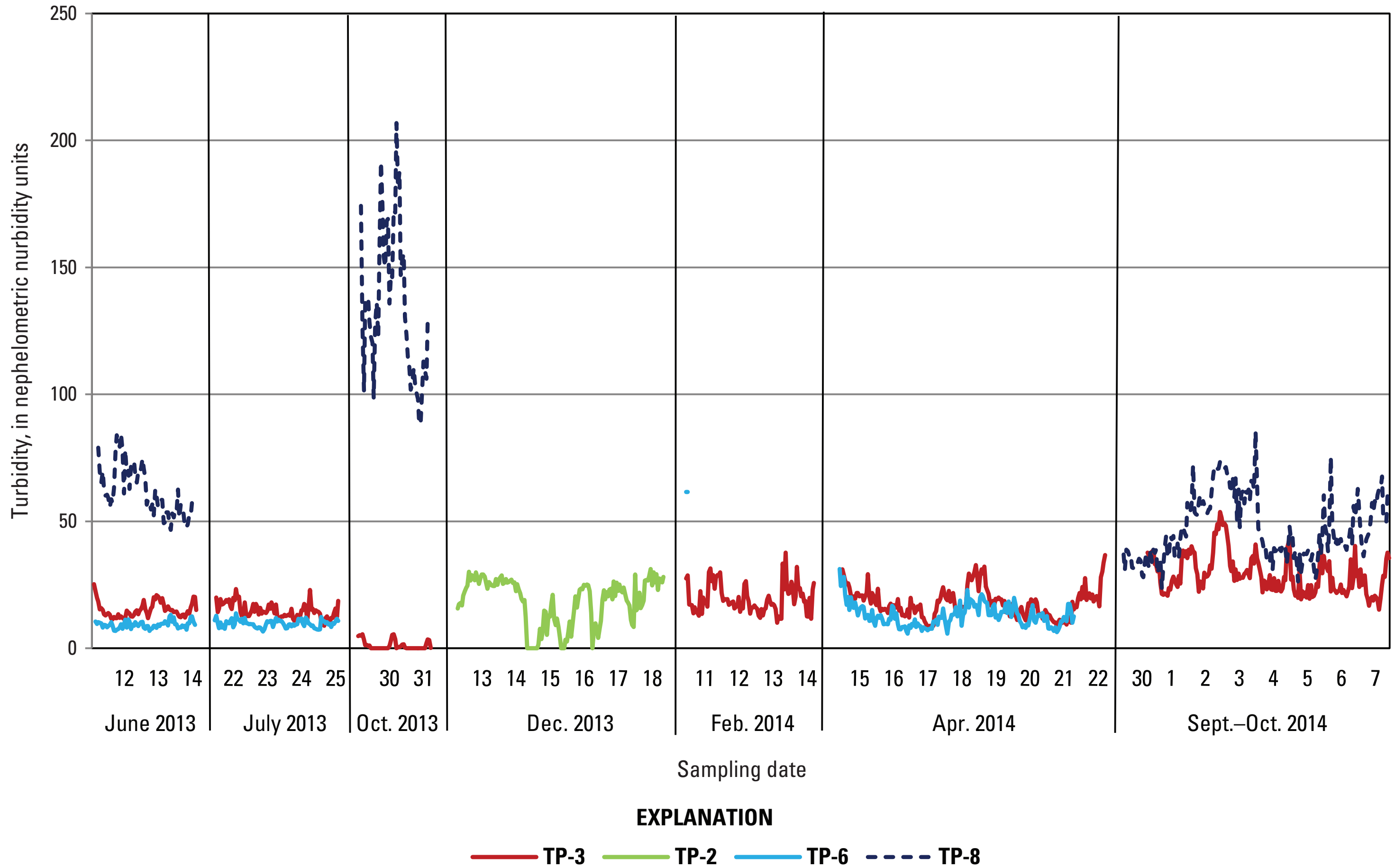

Figure 14. Diurnal turbidity in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 during site visits from June 2013 to September/October 2014.

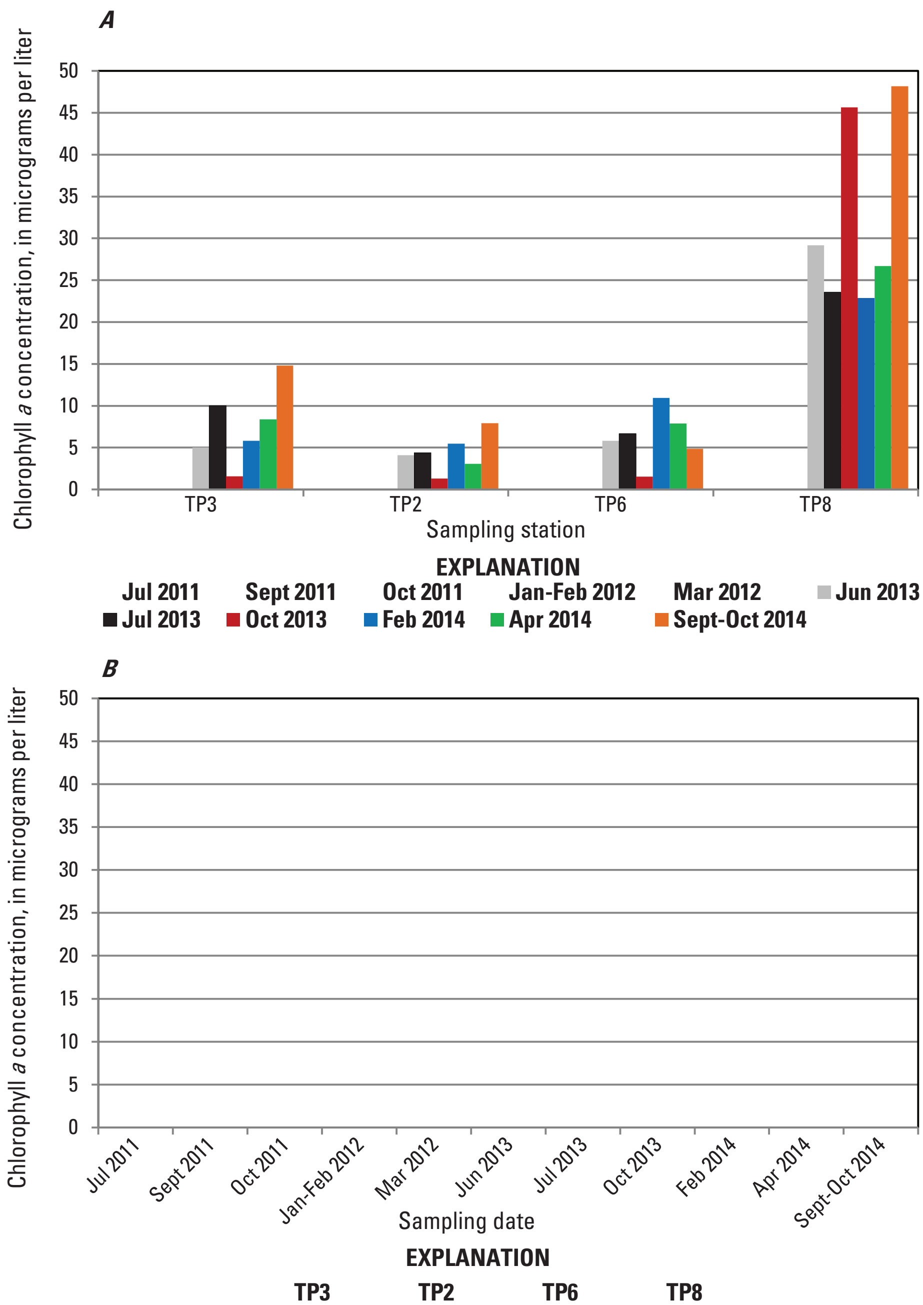

Figure 15. Surface water chlorophyll *a* concentrations in Topock Marsh at sampling stations TP-3, TP-2, TP-6, and TP-8 from July 2011 to October 2014, shown by sampling station (*A*) and by sampling date (*B*). Stations are displayed in upstream to downstream order, but numbering is not sequential.

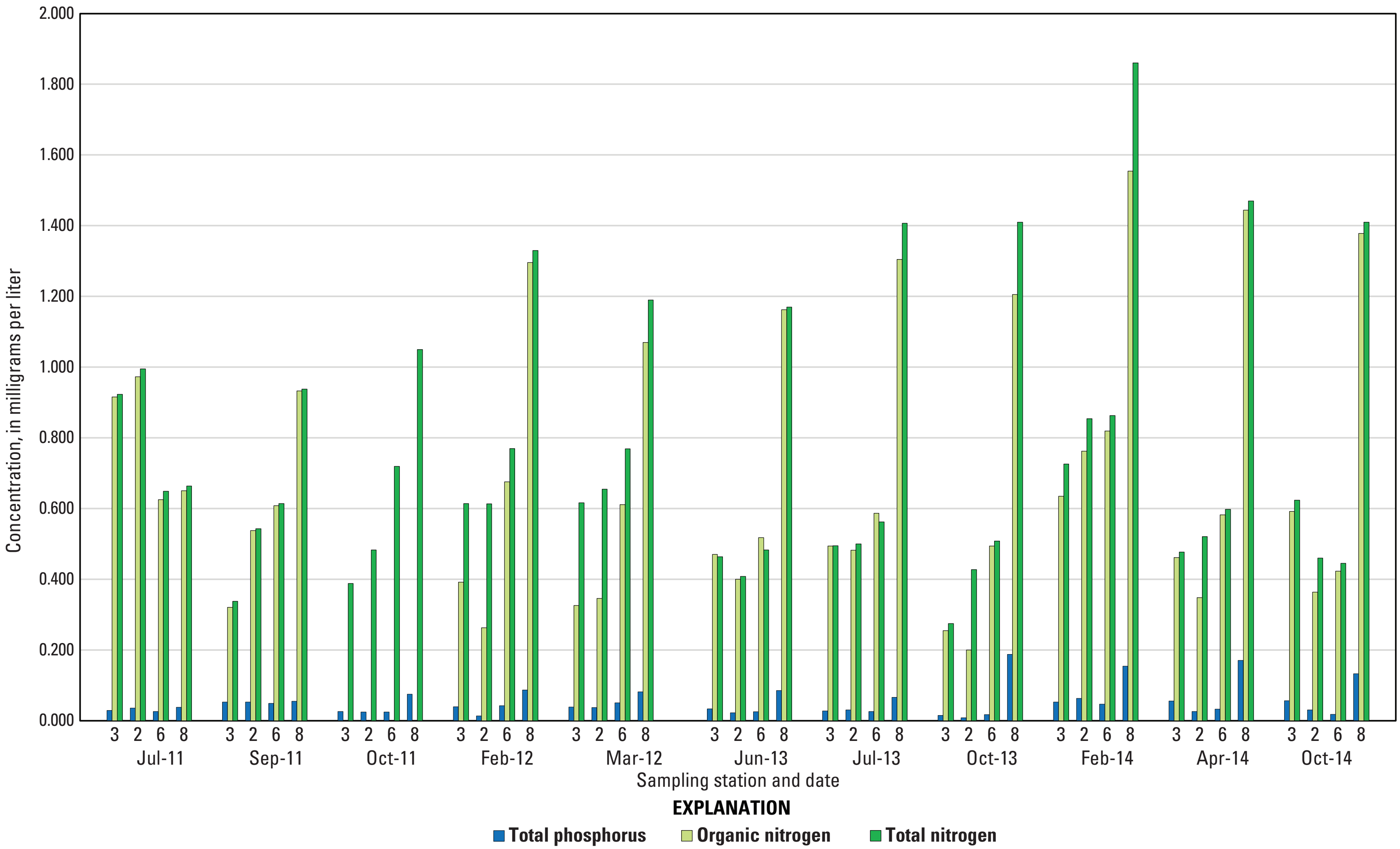

Figure 16. Concentration of total phosphorus, organic nitrogen, and total nitrogen in Topock Marsh at sampling stations TP-3 (3), TP-2 (2), TP-6 (6), and TP-8 (8) during site visits from July 2011 to September/October 2014. Stations are displayed in upstream to downstream order, but numbering is not sequential.

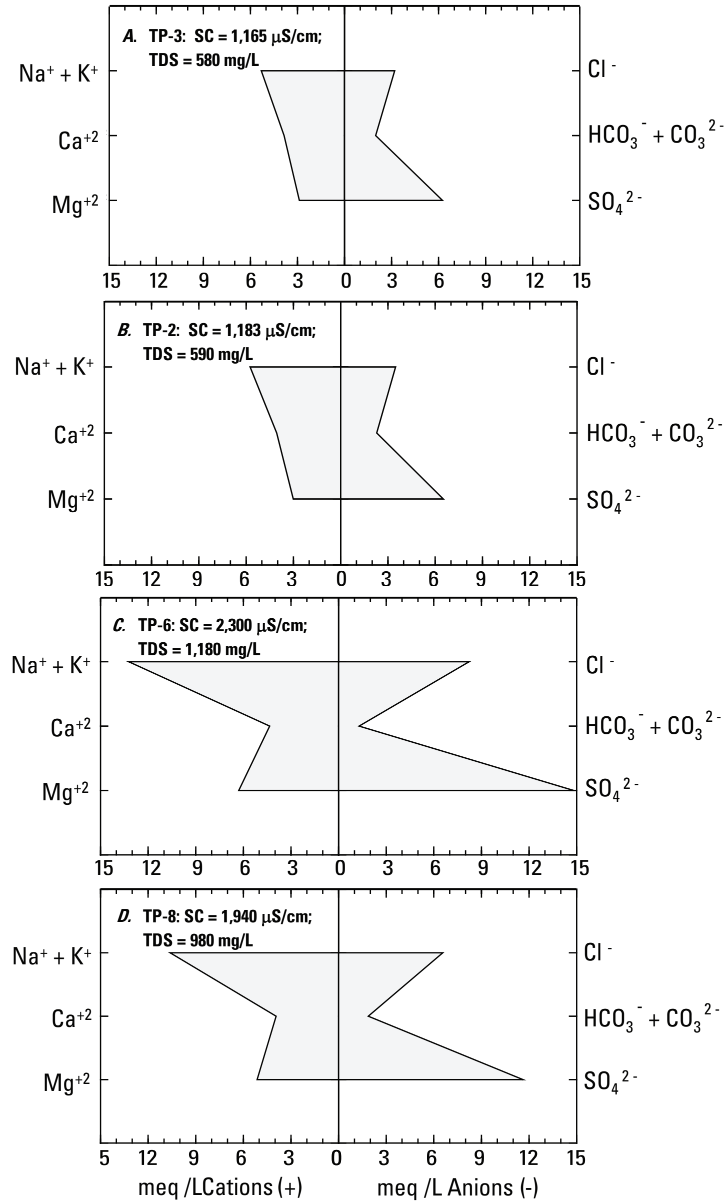

Figure 17. Stiff diagrams showing distribution of major ion chemistry during September/October 2011 in Topock Marsh at sampling stations TP-3 (*A*), TP-2 (*B*), TP-6 (*C*), and TP-8 (*D*). Stations are displayed in upstream to downstream order, but numbering is not sequential. Carbonate and bicarbonate concentrations were calculated from alkalinity. Specific conductance (SC) measured in microsiemens per centimeter (µS/cm), total dissolved solids (TDS) measured in milligrams per liter (mg/L), and ion concentrations measured in milliequivalents per liter (meq/L). (Na, sodium; K, potassium; Cl, chlorine; Ca, calcium; HCO_3, bicarbonate; CO_3, carbonate; Mg, magnesium; SO_4, sulfate)

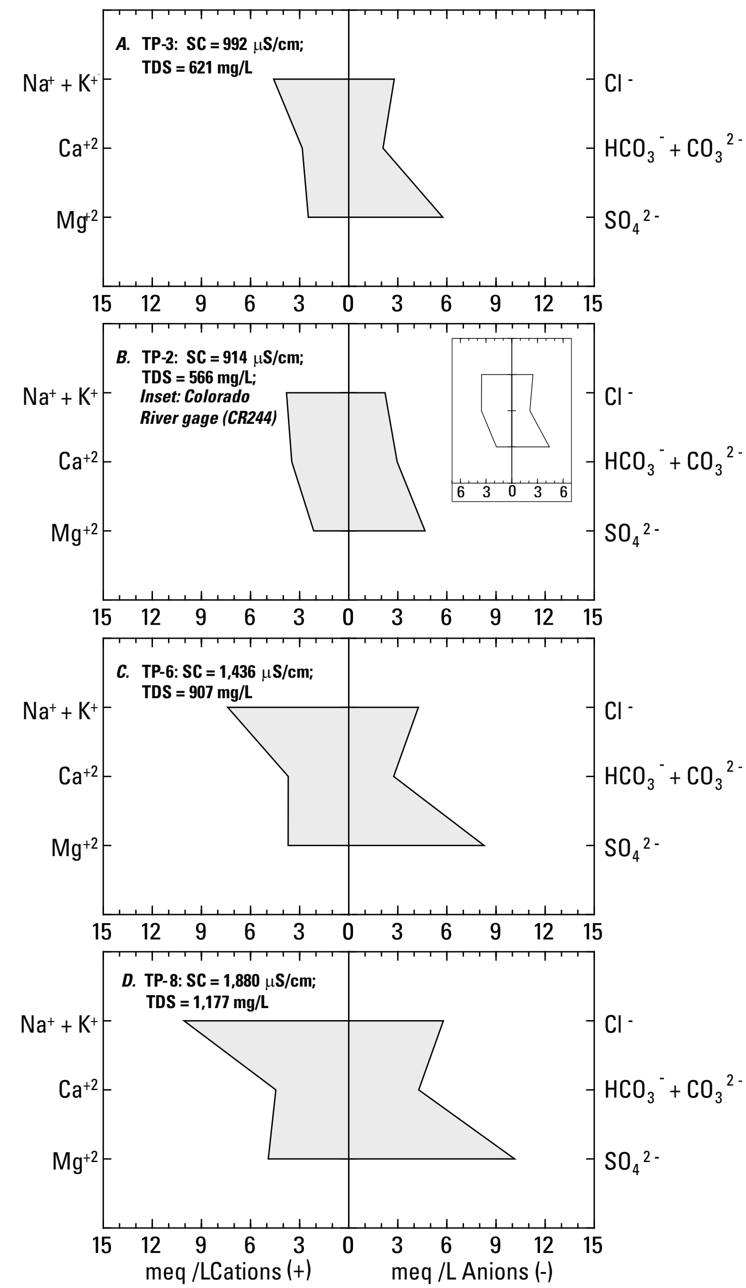

Figure 18. Stiff diagrams showing distribution of major ion chemistry in October 2013 in Topock Marsh at sampling stations TP-3 (*A*), TP-2 (*B*), TP-6 (*C*), and TP-8 (*D*). Stations are displayed in upstream to downstream order, but numbering is not sequential. Carbonate and bicarbonate concentrations were calculated from alkalinity. Data from Colorado River Gage (at CR 244, 2 kilometers upstream of Fire Break Canal, in December 2013) were provided by Scott O'Meara of the Bureau of Reclamation. Specific conductance (SC) measured in microsiemens per centimeter (µS/cm), total dissolved solids (TDS) measured in milligrams per liter (mg/L), and ion concentrations measured in milliequivalents per liter (meq/L). (Na, sodium; K, potassium; Cl, chlorine; Ca, calcium; HCO_3, bicarbonate; CO_3, carbonate; Mg, magnesium; SO_4, sulfate)

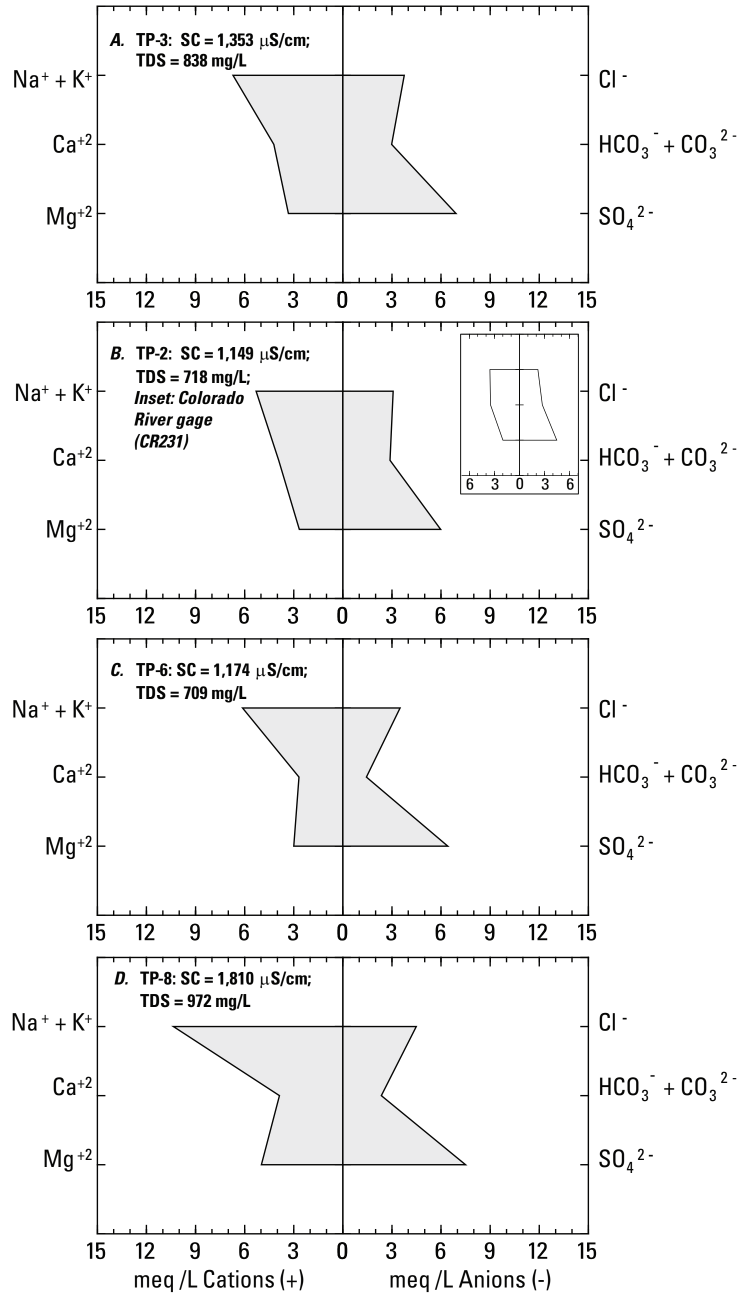

Figure 19. Stiff diagrams showing distribution of major ion chemistry for September 30–October 1, 2014, in Topock Marsh at sampling stations TP-3 (*A*), TP-2 (*B*), TP-6 (*C*), and TP-8 (*D*). Stations are displayed in upstream to downstream order, but numbering is not sequential. Data from Colorado River Gage (at CR231, 6 kilometers below South Dike of Topock Marsh, in September 2014) were provided by Scott O'Meara of the Bureau of Reclamation. Specific conductance (SC) measured in microsiemens per centimeter (µS/cm), total dissolved solids (TDS) measured in milligrams per liter (mg/L), and ion concentrations measured in milliequivalents per liter (meq/L). (Na, sodium; K, potassium; Cl, chlorine; Ca, calcium; HCO_3, bicarbonate; CO_3, carbonate; Mg, magnesium; SO_4, sulfate)

Trace elemental concentrations were similar between all sampling stations and dates (October 2011, June 2013, and September/October 2014). These concentrations were well below the toxicity standards determined by the Arizona Department of Environmental Quality for aquatic and wildlife use (see table 5).

Long-Term Water Chemistry

Long-term water chemistry data for Topock Marsh (from late 1983 through early 2015) are provided in appendix 1 for comparison purposes. TP-8 was our nearest sampling station to Reclamation's long-term sampling location at the marsh's outlet structure in the South Dike (fig. 1). To give an example of these data for making comparisons, we have plotted the historical SC data, because changes in SC can be indicative of major changes in the amount and mobility of ions in the water. Thus, this plot illustrates large variations in SC between seasons and years within Topock Marsh (fig. 20).

Sediment Chemistry

A great deal of variation in sediment chemistry was found among the sediments collected from the four stations during the three collection years of 2011, 2013, and 2014 (table 6). Average nutrient concentrations in the sediment were higher in the October 2011 samples than either the July 2013 or October 2014 samples, and large variations in soil texture existed between sampling dates.

Plant Chemistry

Chemical elements obtained from plant samples are provided in table 7 as percentages and concentrations in milligrams per kilogram (mg/kg), which is equivalent to ppm. Because of the unavailability of submerged vegetation (spiny naiad or Eurasian watermilfoil) in July 2013 and the presence of deep water in the marsh in October 2014, the plant material available to be collected for analyses was not the same in July 2013 and October 2014. Therefore, the results of the analyses varied quite a bit, especially when comparing the percent dry matter of the emergent vegetation, California bulrush (22.3–29.2 percent), to the SAV species, spiny naiad and Eurasian watermilfoil (4.4–8.9 percent). Because the submerged species contained a higher percentage of water in their stems and leaves than the California bulrush, they had lower dry matter percentages (in other words, higher water percentages) and the submerged species contained higher percentages, or concentrations, of most elements measured. The exceptions were B, NO_3-N, and Se. Mean B concentration in the California bulrush was 2.7 times higher than in the average SAV and Eurasian watermilfoil contained the smallest amount (1.5 mg/kg). The mean concentration of NO_3-N in five California bulrush samples (28.9 mg/kg) was three times higher than the SAV samples (mean = 8.8 mg/kg). Selenium concentrations were low throughout all plant samples; however, concentrations in the California bulrush were 320 times higher than in the SAV samples, with a mean of 0.96 mg/kg in the California bulrush compared to 0.003 mg/kg in the SAV (table 7).

There were also large differences in concentrations of some elements between sampling stations for the same plant species. For example, Mn ranged from 96.5 to 431 mg/kg in California bulrush and from 126 to 650 mg/kg in spiny naiad samples. Likewise, aluminum, Cu, and Fe concentrations were higher in plant material collected near TP-2 than at the other locations.

Biological Characteristics

Aquatic Vegetation

Submerged Aquatic Vegetation

The SAV coverage ratings taken at each transect, as well as the water depths and turbidity measurements at each point, are tabularized in table 8 and sampling transects are illustrated in figure 21. Table 9 provides a summary of the presence ratios of the plant species; the ratios are the number of sampling points along a transect that contained at least one submerged aquatic plant divided by the total number of sampling points along a transect. The indigenous spiny naiad was the dominant submerged plant species throughout Topock Marsh during the entire investigation period (2011–14). Sago pondweed (*Stuckenia pectinata*), also indigenous and highly desired by waterfowl, was second in dominance but far less than spiny naiad in presence and coverage (tables 8 and 9). Our initial observations of SAV coverage in July 2011 suggested submerged plant density was low to moderate in shallow (41–89 cm [1.3–2.9 ft] deep), protected areas of the marsh, such as in the vicinity of TP-6 (table 8). However, both species were rare in deeper and more exposed areas, such as along the eastern half of the transect between TP-1 and TP-7 (fig. 21). By September/October 2011, spiny naiad and sago pondweed had grown denser and were more common throughout the shallow protected areas (that is, parts of TP-3, TP-6, TP-5, TP-8, and TP-9), but remained less dense in the open, exposed areas. By the end of January and into March 2012, virtually no spiny naiad was observed in the marsh and only five individual sprigs of sago pondweed were noted (tables 8 and 9).

Table 5. Elemental analyses of water at four sampling stations in Topock Marsh during October 2011, July 2013, and September/October 2014.

[All samples were taken at the sampling stations from just below the water surface. As, arsenic; B, boron; Cd, cadmium; Cr, chromium; Cu, copper; F, fluoride, Fe, iron; Hg, mercury; Mn, manganese; Pb, lead; Se, selenium; Zn, zinc; µg/L, micrograms per liter; TP, sampling station; NA, not available; NWQL, National Water Quality Laboratory; ADEQ, Arizona Department of Environmental Quality]

						October 2011						
Sampling station[1]	**As**	**B**	**Cd**	**Cr [2]**	**Cu**	**F**	**Fe**	**Hg**	**Mn**	**Pb**	**Se [3]**	**Zn**
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
TP-3	2.02	NA	NA	0.68	NA	NA	510.4	0.003	26.10	NA	1.49	NA
TP-2	2.24	NA	NA	0.70	NA	NA	545.1	0.003	30.53	NA	1.43	NA
TP-6	3.73	NA	NA	0.57	NA	NA	427.9	0.001	69.98	NA	1.28	NA
TP-8	5.29	NA	NA	0.98	NA	NA	636.9	0.003	69.37	NA	0.83	NA
October 2011 means	3.32	NA	NA	0.73	NA	NA	530.1	0.002	49.00	NA	1.26	NA
Standard deviations	1.52	NA	NA	0.17	NA	NA	86.5	0.001	23.95	NA	0.30	NA
						July 2013						
Sampling station[1]	**As**	**B**	**Cd**	**Cr 2**	**Cu**	**F**	**Fe**	**Hg**	**Mn**	**Pb**	**Se 3**	**Zn**
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
TP-3	3.93	187	0.019	0.362	<0.700 [4]	585	267	<0.005	12.9	0.83	1.07	2.22
TP-2	3.60	162	0.029	0.302	0.721	509	253	<0.005	15.0	0.78	1.07	2.24
TP-6	3.14	165	0.027	<0.300 [4]	<0.700 [4]	514	193	<0.005	20.0	0.83	1.06	<2.00 [4]
TP-8	4.54	298	0.025	0.431	<0.700 [4]	808	311	<0.005	69.7	1.04	0.63	<2.00 [4]
July 2013 means	3.80	203	0.025	0.278	<0.700	604	256	<0.005	29.4	0.87	0.96	1.62
Standard deviations	0.59	64.3	0.004	0.183	0.186	140	49		27.0	0.12	0.22	0.71
						September 30, 2014–October 1, 2014						
Sampling station[1]	**As**	**B**	**Cd**	**Cr 2**	**Cu**	**F**	**Fe**	**Hg**	**Mn**	**Pb**	**Se 3**	**Zn**
	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
TP-3	4.14	187	<0.030	NA	1.23	473	635	<0.005	39.9	2.76	1.00	2.23
TP-2	3.35	147	<0.030	NA	<0.800 [5]	407	295	<0.005	21.4	1.53	1.31	<2.00
TP-6-1	3.60	176	<0.030	NA	0.95	418	78	<0.005	6.9	0.22	0.55	<2.00
TP-6-2	3.84	176	<0.030	NA	<0.800 [5]	447	73	<0.005	6.6	0.23	0.59	<2.00
TP-8	6.06	288	<0.030	NA	1.27	530	720	<0.005	190.0	2.29	0.44	<2.00
September/October 2014 mean	4.20	195	<0.030	NA	0.850	455	360	<0.005	53.0	1.41	0.78	2.23
Standard deviation	1.08	54		NA	0.429	49	305		77.8	1.16	0.37	
NWQL Laboratory Codes	3123	2354	2376	NA	3129	651	2359	2708	2363	2380	3133	2371
NWQL minimum reporting level	0.2 and .28	2	0.03	0.3	0.800	10	4.6	0.005	0.20	0.04	0.05	2
ADEQ[5] acute toxicity standard	340							2.40	980			
ADEQ chronic toxicity standard	150			100			1,000	0.01			2.00	

[1]Sampling stations are displayed in upstream to downstream order.

[2]Chronium analyses in 2014 were not done due to low levels in 2013 and the cost of analyses.

[3]The U.S. Environmenntal Protection Agency (EPA) is reviewing selenium standards and only chronic criteria (5.0 ug/L for freshwater) are available on their online compilation (EPA, 2012). In a draft report, the EPA (2004) recommends acute criteria should be based on the relative proportion of selenite, and chronic criteria should be based on selenium concentrations within fish tissue.

[4]Means including "less than (<)" values are calculated using half of the detection limits for analyzed parameters.

[5]The standards recommended by the Arizona Department of Environmental Quality (ADEQ) are specific to warmwater lakes and reservoirs designated for aquatic and wildlife use. Ranges apply to peak season (April to October for warmwater lakes [ADEQ, 2009]).

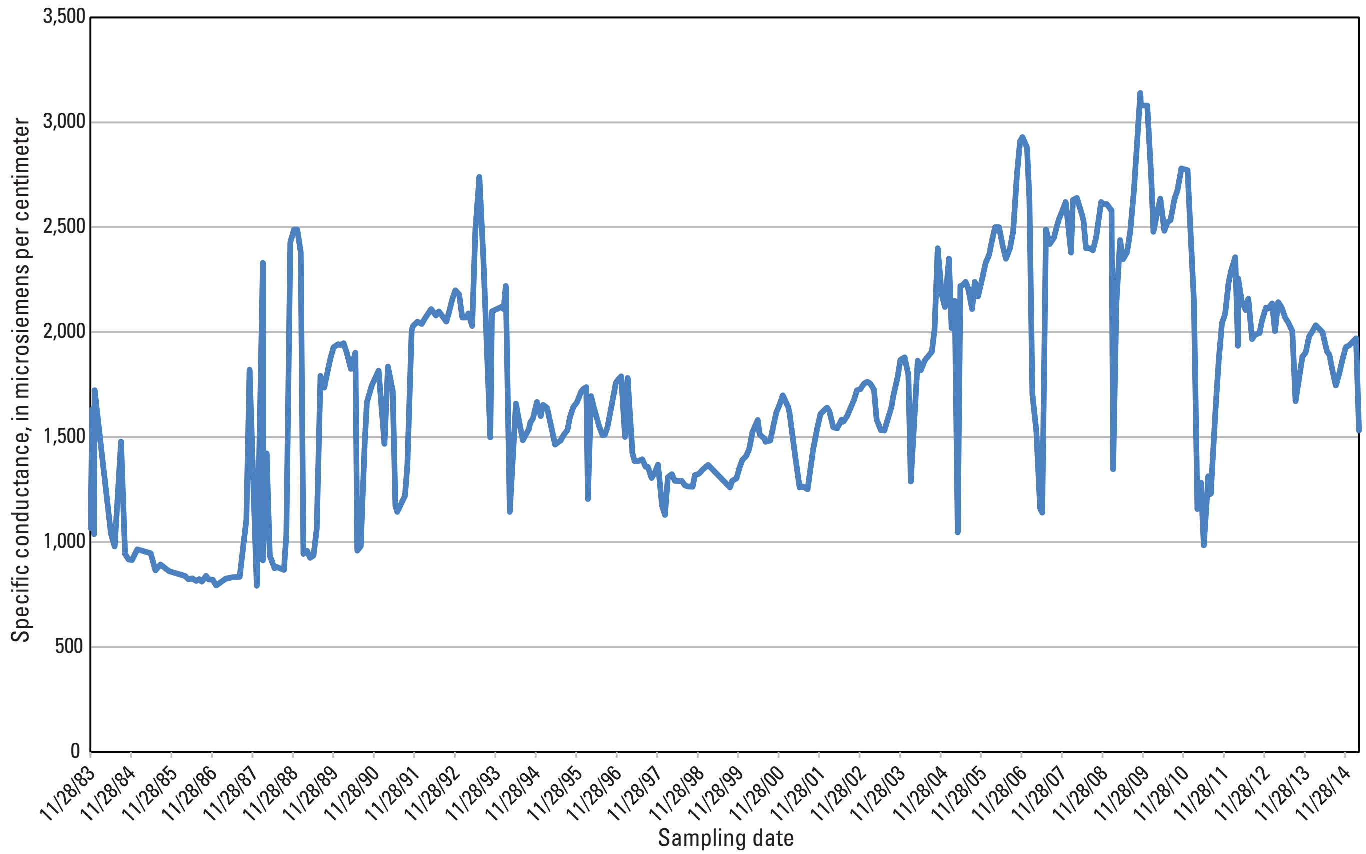

Figure 20. Historical specific conductance in Topock Marsh from November 1983 to April 2015. Samples were collected at the outlet structure in the South Dike and data were provided by Janet Kirsch, Bureau of Reclamation, Lower Colorado Region, 2015.

Table 6. Analyses of Topock Marsh sediment samples collected in October 2011, July 2013, and October 2014.

[AB-DTPA, ammonium bicarbonate diethylene triamine penta acetic acid (analysis method); mg/L, milligram per liter; EC, electrical conductivity; mS/cm, millisiemens per centimeter; %, percentage; OM, organic matter; NO_3–N, nitrate-nitrogen; P, phosphorus; K, potassium; Zn, zinc; Fe, iron; Mn, manganese; Cu, copper; TP, sampling station; Rep., replicate; ppm, parts per million; S, sulfur; B, boron; mg/kg, milligrams per kilogram; Cr, chromium; Cd, cadmium; Pb, lead; Mo, molybdenum; As, arsenic; Se, selenium; Hg, mercury; NA, not applicable; NH_4OAc, ammonium acetate (extraction method); Ca, calcium; Na, sodium]

Sample date	Sampling station[1]	Paste		Lime estimate	% OM	AB-DTPA mg/L							Texture Estimate
		pH	EC mS/cm			NO_3–N	P	K	Zn	Fe	Mn	Cu	
October 2011	TP-3	7.8	1.5	Very high	1.5	1.6	0.5	154	2.6	127	8.2	4.8	Clay
	TP-2	7.6	2.8	Very high	5.1	1.3	1.6	288	6.2	280	22.5	12.1	Clay
	TP-6	7.8	3.2	Very high	4.9	2.3	25.2	390	4.9	373	18.5	10.8	Clay
	TP-8	7.7	3.2	Very high	5.8	0.5	5.5	263	2.4	128	13.0	6.0	Clay
October 2011 means		**7.7**	**2.7**		**4.3**	**1.4**	**8.2**	**273.8**	**4.0**	**226.8**	**15.6**	**8.4**	
July 2013	TP-3	7.6	1.3	Medium	7.8	0.75	1.2	210.5	3.1	238.5	4.9	6.8	Silty clay loam
	TP-2	7.7	0.9	Medium	0.6	0.49	0.4	57.0	0.5	28.6	0.7	1.2	Loamy sand
	TP-6 Rep 1	7.6	1.5	High	1.1	0.28	0.5	56.4	0.8	44.0	7.8	0.7	Loamy sand
	TP-6 Rep 2	7.5	1.6	High	0.9	0.34	1.0	62.4	1.0	45.9	1.9	1.2	Loamy sand
	TP-8	7.7	2.5	Very high	6.6	0.35	2.5	538.1	2.7	256.4	18.1	9.4	Sandy clay loam
July 2013 means		**7.6**	**1.6**		**3.4**	**0.44**	**1.1**	**184.9**	**1.6**	**122.7**	**6.7**	**3.9**	
October 2014	TP-3	7.9	0.9	High	2.6	0.39	2.0	62.3	0.9	70.3	2.0	1.3	Sandy loam
	TP-2	7.6	1.8	Very high	5.6	0.42	2.0	190	5.1	128.0	9.3	8.4	Clay loam
	TP-6	7.7	2.4	Very high	5.5	0.43	5.0	229	8.4	111.1	7.9	6.5	Clay loam
	TP-8	8.0	1.3	Very high	1.1	0.18	1.5	84.8	0.9	97.7	5.5	1.0	Sandy loam
	TP-9	7.9	1.3	Very high	1.6	0.42	1.5	104	1.0	52.8	3.6	1.2	Clay loam
October 2014 means		**7.8**	**1.5**		**3.3**	**0.37**	**2.4**	**134.0**	**3.3**	**92.0**	**5.7**	**3.7**	

Table 6. Analyses of Topock Marsh sediment samples collected in October 2011, July 2013, and October 2014.—Continued

[AB-DTPA, ammonium bicarbonate diethylene triamine penta acetic acid (analysis method); mg/L, milligram per liter; EC, electrical conductivity; mS/cm, millisiemens per centimeter; %, percentage; OM, organic matter; NO_3–N, nitrate-nitrogen; P, phosphorus; K, potassium; Zn, zinc; Fe, iron; Mn, manganese; Cu, copper; TP, sampling station; Rep., replicate; ppm, parts per million; S, sulfur; B, boron; mg/kg, milligrams per kilogram; Cr, chromium; Cd, cadmium; Pb, lead; Mo, molybdenum; As, arsenic; Se, selenium; Hg, mercury; NA, not applicable; NH_4OAc, ammonium acetate (extraction method); Ca, calcium; Na, sodium]

Sample date	Sampling station[1]	Extract-able ppm S	Hot water extract B mg/kg	Extractable Cr	Extractable Cd	Extractable Pb	Extractable Mo	Extractable As[2]	Extractable Se[2]	Extractable Hg[2]	
				mg/kg							
October 2011	TP-3	NA	NA	<0.01	NA	NA	NA	0.04	0.82	<0.005	
	TP-2	NA	NA	<0.01	NA	NA	NA	0.03	0.71	<0.005	
	TP-6	NA	NA	<0.01	NA	NA	NA	0.15	1.4	<0.005	
	TP-8	NA	NA	<0.01	NA	NA	NA	0.05	0.39	<0.005	
October 2011 means				**<0.01**				**0.07**	**0.83**	**<0.005**	
								Total As	Total Se	Total Hg	
July 2013	TP-3	392	4.8	0.02	0.06	5.00	0.21	3.12	0.015	0.015	
	TP-2	111	3.3	0.01	0.02	0.77	0.12	1.01	0.009	0.009	
	TP-6 Rep 1	174	3.1	0.01	0.02	0.61	0.08	2.61	0.012	0.011	
	TP-6 Rep 2	208	2.9	0.01	0.02	0.75	0.06	2.60	0.010	0.010	
	TP-8	1,163	7.0	0.03	0.01	3.60	0.58	4.71	0.008	0.005	
July 2013 means		**409.6**	**4.2**	**0.02**	**0.03**	**2.15**	**0.21**	**2.81**	**0.011**	**0.010**	
				NH_4OAc Ca	NH_4OAc Mg	NH_4OAc Na		Total As[2]	Total Se[2]	Total Hg[2]	% Dry matter
October 2014	TP-3	250	1.61	9.5	2.2	0.6		1.90	0.014	0.013	57.43
	TP-2	953	2.19	18.3	5.7	1.8		7.48	0.010	0.011	30.98
	TP-6	700	2.21	13.8	4.7	1.8		2.70	0.015	0.009	20.22
	TP-8	162	1.72	8.8	2.4	1.0		2.43	0.018	0.010	74.76
	TP-9	427	2.48	10.8	3.8	1.5		3.03	0.013	0.014	46.49
October 2014 means		**498.4**	**2.0**	**12.2**	**3.8**	**1.3**		**3.51**	**0.014**	**0.011**	**45.98**

[1]Sampling stations are displayed in upstream to downstream order.

[2]Values were below established threshold effects of 5.9 mg/kg for As (with one exception as shown in red), 0.174 mg/kg for Hg, and 2.0 mg/kg for Se (MacDonald and others, 2000; Lemly, 2002).

Table 7. Analyses of Topock Marsh plant samples collected in July 2013 and October 2014.

[%, percentage; mg/kg, milligrams per kilogram; N, nitrogen; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; P, phosphorus; S, sulfur; Fe, iron; Mn, manganese; Cu, copper; Zn, zinc; TP, sampling station; Rep, replicate; B, boron; NO_3-N, nitrate-nitrogen; Mo, molybdenum; Al, aluminum; As, arsenic; Se, selenium; Hg, mercury; Cr, chromium]

Sample date	Sampling station[1]	%							mg/kg			
		N	Ca	Mg	Na	K	P	S	Fe	Mn	Cu	Zn
July 2013	TP-3	0.60	0.16	0.09	0.38	0.81	0.45	0.23	57.3	431	0.99	5.11
	TP-2	0.52	0.19	0.10	0.30	0.83	0.55	0.16	74.1	106	1.61	4.90
	TP-6 Rep 1	0.46	0.18	0.07	0.57	1.16	0.22	0.26	44.9	177	0.66	4.19
	TP-6 Rep 2	0.47	0.11	0.05	0.28	0.99	0.13	0.15	56.0	96.5	0.42	2.75
	TP-8	0.50	0.19	0.12	1.03	0.81	0.22	0.56	50.9	137	0.31	1.48
July 2013 means		0.51	0.17	0.09	0.51	0.92	0.31	0.27	56.63	189.42	0.80	3.69
October 2014	TP-3	2.36	4.72	0.53	1.78	2.04	0.15	0.27	1,493	182	3.56	18.0
	TP-2	2.09	1.96	0.74	1.69	2.62	0.17	0.73	2,199	523	5.28	17.8
	TP-6	1.69	2.49	0.76	0.66	1.26	0.09	0.30	972	126	2.54	10.8
	TP-8	1.80	0.78	0.77	1.93	1.90	0.28	0.85	342	136	1.58	7.3
	TP-9	1.54	3.16	0.85	0.49	1.09	0.13	0.33	1,756	650	3.15	16.8
October 2014 means		1.90	2.62	0.73	1.31	1.78	0.16	0.50	1,352.40	323.40	3.22	14.13

Sample date	Sampling station[1]	mg/kg								% Dry matter	Plant species[3]
		B	NO_3-N	Mo	Al	As[2]	Se[2]	Hg[2]	Cr[2]		
July 2013 continued	TP-3	34.9	49.5	0.06	64.8	0.001	0.89	<0.001	0.99	25.1	California bulrush
	TP-2	43.0	24.5	0.13	122	0.48	1.09	<0.001	0.94	25.3	California bulrush
	TP-6 Rep 1	31.6	42.8	0.10	79.0	0.39	0.82	<0.001	1.65	28.2	California bulrush
	TP-6 Rep 2	31.4	20.7	<0.01	40.7	0.52	0.80	<0.001	1.26	22.3	California bulrush
	TP-8	35.0	7.0	0.06	50.8	0.37	1.20	<0.001	1.19	29.2	California bulrush
July 2013 means continued		35.17	28.90	0.07	71.49	0.35	0.96	<0.001	1.21	26.02	
October 2014 continued	TP-3	8.2	12.6	0.26	2,147	1.86	0.003	<0.001	NA	8.9	spiny naiad
	TP-2	1.5	10.6	0.09	4,968	1.88	0.001	<0.001	NA	4.5	Eurasian watermilfoil
	TP-6	15.9	5.9	0.09	1,481	0.82	0.004	<0.001	NA	4.8	spiny naiad
	TP-8	16.6	7.9	0.06	264	1.06	0.002	<0.001	NA	4.4	spiny naiad
	TP-9	22.2	6.9	0.34	2,994	2.67	0.004	<0.001	NA	6.2	spiny naiad
October 2014 means continued		12.89	8.77	0.17	2,370.80	1.66	0.003	<0.001		5.76	

[1]Sampling stations are displayed in upstream to downstream order.

[2]Values were below established threshold effects (MacDonald and others, 2000; Lemly, 1993, 2002).

[3]Plant species - California bulrush, Schoenoplectus acutus; spiny naiad, Najas marina; Eurasian watermilfoil, Myriophyllum spicatum

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	07/27/2011	July	2011	726844	3850961	0.41	0.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726848	3850964	0.41	5.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726853	3850966	1.13	10.0		No	0	0	0	0
TP-6	07/27/2011	July	2011	726860	3850971	0.61	20.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726874	3850980	0.74	38.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726889	3850990	0.86	57.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726904	3850999	0.83	75.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726918	3851008	0.71	93.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726933	3851017	0.86	112.0		Yes	2	0	0	0
TP-6	07/27/2011	July	2011	726945	3851030	0.89	130.0		Yes	2	0	0	0
TP-8	07/28/2011	July	2011	729836	3847285	1.52			No	0	0	0	0
TP-8	07/28/2011	July	2011	729837	3847287	1.58			Yes	1	0	0	0
TP-8	07/28/2011	July	2011	729837	3847288	1.55			No	0	0	0	0
TP-8	07/28/2011	July	2011	729839	3847292	1.46			No	0	0	0	0
TP-8	07/28/2011	July	2011	729840	3847296	1.37			Yes	1	0	0	0
TP-8	07/28/2011	July	2011	729842	3847301	1.31			No	0	0	0	0
TP-8	07/28/2011	July	2011	729844	3847306	1.07			No	0	0	0	0
TP-8	07/28/2011	July	2011	729846	3847310	0.76			No	0	0	0	0
TP-8	07/28/2011	July	2011	729848	3847331	0.70			No	0	0	0	0
TP-3	07/28/2011	July	2011	727395	3856319	1.01			No	0	0	0	0
TP-3	07/28/2011	July	2011	727399	3856319	0.67			Yes	2	0	0	0
TP-2	07/28/2011	July	2011	726434	3854550	2.59			No	0	0	0	0
TP-2	07/28/2011	July	2011	726439	3854550	1.06			No	0	0	0	0
TP-5	07/28/2011	July	2011	728436	3848187	0.73			Yes	1	0	0	0
TP-1	07/28/2011	July	2011	N/A	N/A	1.52			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727312	3856305	0.30			Yes	3	1	0	0
TP-3	09/20/2011	Sept.	2011	727312	3856305	0.61			Yes	3	1	0	0
TP-3	09/20/2011	Sept.	2011	727315	3856305	0.61			Yes	3	0	0	0
TP-3	09/20/2011	Sept.	2011	727318	3856305	0.99			Yes	1	0	0	0
TP-3	09/20/2011	Sept.	2011	727324	3856305	1.57			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727330	3856305	2.18			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727345	3856305	2.31			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727373	3856305	0.74			Yes	2	0	0	0
TP-3	09/20/2011	Sept.	2011	727403	3856305	0.61			Yes	0	0	1	0
TP-3	09/20/2011	Sept.	2011	727434	3856307	0.61			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727480	3856309	0.91			No	0	0	0	0
TP-3	09/20/2011	Sept.	2011	727522	3856312	0.66			Yes	2	0	0	0
TP-3	09/20/2011	Sept.	2011	727563	3856318	0.61			Yes	2	0	0	0
TP-3	09/20/2011	Sept.	2011	727570	3856321	0.61			Yes	3	0	0	0
TP-3	09/20/2011	Sept.	2011	727572	3856322	0.46			Yes	3	0	0	0
TP-3	09/20/2011	Sept.	2011	727576	3856325	0.30			Yes	3	0	0	0
TP-2	09/20/2011	Sept.	2011	726390	3854554	0.74			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726391	3854555	1.27			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726396	3854556	2.29			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726435	3854557	1.19			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726473	3854558	0.76			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726526	3854559	0.61			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726579	3854605	0.61			No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-2	09/20/2011	Sept.	2011	726632	3854607	0.61			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726685	3854609	0.51			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726738	3854611	0.51			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726787	3854615	0.48			Yes	0	2	0	0
TP-2	09/20/2011	Sept.	2011	726795	3854617				No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	726993	3854636	0.46			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	727043	3854623	0.46			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	727203	3854626	0.46			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	727363	3854629	0.46			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	727523	3854632	0.46			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	727691	3854644	0.37			Yes	3	0	0	0
TP-2	09/20/2011	Sept.	2011	727819	3854615	0.56			Yes	0	1	0	0
TP-2	09/20/2011	Sept.	2011	727906	3854615	0.66			Yes	0	1	0	0
TP-2	09/20/2011	Sept.	2011	727992	3854614	0.71			No	0	0	0	0
TP-2	09/20/2011	Sept.	2011	728126	3854613	0.46			Yes	0	1	0	0
TP-1	09/20/2011	Sept.	2011	728059	3853217	0.30			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	728058	3853216	0.46			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727998	3853156	1.07			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727937	3853095	0.99			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727876	3853034	0.30			Yes	1	1	0	0
TP-1	09/20/2011	Sept.	2011	727725	3852980	0.61			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727815	3852975	0.61			Yes	1	1	0	0
TP-1	09/20/2011	Sept.	2011	727754	3852971	0.79			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727693	3852968	0.76			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	727632	3852965	0.48			Yes	1	1	0	0
TP-1	09/20/2011	Sept.	2011	727586	3852963	0.46			Yes	1	1	0	0
TP-1	09/20/2011	Sept.	2011	727267	3852931	0.48			Yes	0	2	0	0
TP-1	09/20/2011	Sept.	2011	726550	3853569	0.48			Yes	0	1	0	0
TP-1	09/20/2011	Sept.	2011	726106	3853617	0.71			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	726012	3853617	1.32			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011			0.94			No	0	0	0	0
TP-1	09/20/2011	Sept.	2011	726020	3853592	0			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	726794	3850995	0.27			Yes	3	1	0	0
TP-6	09/22/2011	Sept.	2011	726800	3851005	0.37			Yes	3	1	0	0
TP-6	09/22/2011	Sept.	2011	726806	3851005	0.55			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726845	3851005	0.61			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726906	3851007	0.61			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726936	3851009	0.61			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726951	3851011	0.61			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726966	3851013	0.73			Yes	3	0	0	0
TP-6	09/22/2011	Sept.	2011	726997	3851015	0.71			Yes	2	1	0	0
TP-6	09/22/2011	Sept.	2011	727149	3851017	0.71			Yes	1	1	0	0
TP-6	09/22/2011	Sept.	2011	727302	3851019	0.86			Yes	1	0	0	0
TP-6	09/22/2011	Sept.	2011	727607	3851021	1.09			Yes	0	1	0	0
TP-6	09/22/2011	Sept.	2011	727759	3851023	0.94			Yes	1	0	0	0
TP-6	09/22/2011	Sept.	2011	727881	3851024	1.35			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	728003	3851025	1.02			Yes	1	0	0	0
TP-6	09/22/2011	Sept.	2011	728125	3851027	0.86			Yes	2	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	09/22/2011	Sept.	2011	728210	3851030	0.79			Yes	1	0	0	0
TP-6	09/22/2011	Sept.	2011	728260	3851030	1.40			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	728443	3851030	1.22			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	728449	3851030	0.91			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	728455	3851030	0.64			No	0	0	0	0
TP-6	09/22/2011	Sept.	2011	728458	3851021	0			No	0	0	0	0
Between TP-6 and TP-5	09/22/2011	Sept.	2011	N/A	N/A	1.07			Yes	2.5	0	0	0
Between TP-6 and TP-5	09/22/2011	Sept.	2011	N/A	N/A	0.30			Yes	2.5	1	0	0
TP-5	09/22/2011	Sept.	2011	728436	3848187	0.56			Yes	3	2	0	0
TP-5	09/22/2011	Sept.	2011	728438	3848187	0.69			Yes	3	2	0	0
TP-5	09/22/2011	Sept.	2011	728442	3848187	0.74			Yes	2	3	0	0
TP-5	09/22/2011	Sept.	2011	728443	3848187	0.76			Yes	2	3	0	0
TP-5	09/22/2011	Sept.	2011	728451	3848187	1.07			Yes	3	0	0	0
TP-5	09/22/2011	Sept.	2011	728466	3848187	1.57			Yes	2	0	0	0
TP-5	09/22/2011	Sept.	2011	728557	3848227	1.57			Yes	2	0	0	0
TP-5	09/22/2011	Sept.	2011	728664	3848274	1.83			Yes	1.5	0	0	0
TP-5	09/22/2011	Sept.	2011	728760	3848294	1.83			Yes	2	0	0	0
TP-5	09/22/2011	Sept.	2011	728863	3848314	1.68			Yes	1	0	0	0
TP-5	09/22/2011	Sept.	2011	728976	3848320	1.83			No	0	0	0	0
TP-5	09/22/2011	Sept.	2011	729089	3848326	1.91			No	0	0	0	0
TP-5	09/22/2011	Sept.	2011	729172	3848334	1.96			Yes	1	0	0	0
TP-5	09/22/2011	Sept.	2011	729275	3848342	1.52			Yes	1	0	0	0
TP-5	09/22/2011	Sept.	2011	729378	3848350	1.12			Yes	3	1	0	0
TP-5	09/22/2011	Sept.	2011	729392	3848358	0.61			Yes	3	0	0	0
TP-5	09/22/2011	Sept.	2011	729400	3848366	0.56			Yes	3	0	0	0
TP-5	09/22/2011	Sept.	2011	729403	3848374	0.25			Yes	3	0	0	0
TP-5	09/22/2011	Sept.	2011	729405	3848382	0.15			Yes	3	0	0	0
TP-5	09/22/2011	Sept.	2011	729443	3848389	0.08			Yes	2	1	0	0
TP-8	09/22/2011	Sept.	2011	730114	3847310	0.30			Yes	1	3	0	0
TP-8	09/22/2011	Sept.	2011	730113	3847310	0.36			Yes	1	3	0	0
TP-8	09/22/2011	Sept.	2011	730111	3847310	0.36			Yes	1	3	0	0
TP-8	09/22/2011	Sept.	2011	730108	3847307	0.36			Yes	1	3	0	0
TP-8	09/22/2011	Sept.	2011	730102	3847307	0.71			Yes	3	1	0	0
TP-8	09/22/2011	Sept.	2011	730096	3847307	1.12			Yes	3	0	0	0
TP-8	09/22/2011	Sept.	2011	730084	3847305	1.22			Yes	2	0	0	0
TP-8	09/22/2011	Sept.	2011	730068	3847305	1.37			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	730053	3847305	1.37			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	729953	3847295	1.37			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	729836	3847285	1.78			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	729753	3847275	1.52			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	729653	3847265	1.65			Yes	1	0	0	0
TP-8	09/22/2011	Sept.	2011	729552	3847255	1.19			Yes	2	0	0	0
TP-8	09/22/2011	Sept.	2011	729452	3847250	1.65			No	0	0	0	0
TP-8	09/22/2011	Sept.	2011	729352	3847250	1.52			No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

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				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-8	09/22/2011	Sept.	2011	729337	3847245	1.30			Yes	3	0	0	0
TP-8	09/22/2011	Sept.	2011	729343	3847235	1.22			Yes	3	0	0	0
TP-8	09/22/2011	Sept.	2011	729331	3847225	0.79			Yes	3	1	0	0
TP-8	09/22/2011	Sept.	2011	729325	3847215	0.30			Yes	3	3	0	0
TP-8	09/22/2011	Sept.	2011	729323	3847205	0.30			Yes	3	3	0	0
TP-8	09/22/2011	Sept.	2011	729323	3847189	0.30			Yes	3	3	0	0
Topock 6-1 thru channels	09/22/2011	Sept.	2011	N/A	N/A	≤0.91			Yes	2.5	0	0	0
TP-0	10/24/2011	Oct..	2011	726688	3857706	0.30			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726690	3857707	0.91			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726691	3857707	1.22			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726693	3857708	1.52			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726699	3857708	2.59			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726708	3857709	0.72			Yes	3	0	0	0
TP-0	10/24/2011	Oct.	2011	726719	3857710	2.13			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726750	3857709	2.07			Yes	1	0	0	0
TP-0	10/24/2011	Oct.	2011	726780	3857713	3.14			Yes	1	0	0	0
TP-0	10/24/2011	Oct.	2011	726811	3857717	0.70			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726848	3857730	1.25			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726896	3857755	0.46			Yes	2	0	0	0
TP-0	10/24/2011	Oct.	2011	726921	3857770	0.30			Yes	2	2	0	0
TP-1	10/24/2011	Oct.	2011	726020	3853594	0.73			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726022	3853594	0.82			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726023	3853594	0.91			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726032	3853590	1.95			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726044	3853586	0.76			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726066	3853582	0.58			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726096	3853578	0.61			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011			0.64			Yes	1	0	0	0
TP-1	10/24/2011	Oct.	2011	726331	3853570	0.64			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726449	3853566	0.70			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726566	3853562	0.61			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	726683	3853558	0.58			Yes	2	0	0	0
TP-1	10/24/2011	Oct.	2011	726801	3853554	0.40			Yes	2	0	0	0
TP-1	10/24/2011	Oct.	2011	726918	3853550	0.40			Yes	1	0	0	0
TP-1	10/24/2011	Oct.	2011	727036	3853521	0.49			Yes	0	1	0	0
TP-1	10/24/2011	Oct.	2011	727153	3853492	0.61			Yes	0	1	0	0
TP-1	10/24/2011	Oct.	2011	727271	3853463	0.79			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727388	3853434	0.91			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727506	3853405	0.88			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727623	3853376	0.91			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727740	3853347	1.10			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727858	3853318	1.13			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	727975	3853289	0.98			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	728093	3853260	0.94			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	728105	3853257	0.91			Yes	1	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

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				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-1	10/24/2011	Oct.	2011	728119	3853254	0.58			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	728120	3853254	0.46			Yes	1	0	0	0
TP-1	10/24/2011	Oct.	2011	728122	3853253	0.46			No	0	0	0	0
TP-1	10/24/2011	Oct.	2011	728066	3853253	0			No	0	0	0	0
TP-9	10/24/2011	Oct.	2011	730380	3846849	0.06			Yes	0	0	1	0
TP-9	10/24/2011	Oct.	2011	730378	3846849	0.30			Yes	0	2	0	0
TP-9	10/24/2011	Oct.	2011	730377	3846849	0.46			Yes	2	1	0	0
TP-9	10/24/2011	Oct.	2011	730375	3846849	0.61			Yes	3	0	0	0
TP-9	10/24/2011	Oct.	2011	730368	3846849	0.61			Yes	3	0	0	0
TP-9	10/24/2011	Oct.	2011	730362	3846849	0.84			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	730298	3846815	0.76			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	730234	3846815	0.46			Yes	3	1	0	0
TP-9	10/24/2011	Oct.	2011	730171	3846815	0.61			Yes	3	0	0	0
TP-9	10/24/2011	Oct.	2011	730107	3846815	0.86			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	730043	3846815	0.30			Yes	0	2	0	0
TP-9	10/24/2011	Oct.	2011	729979	3846815	0.61			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	729915	3846815	0.76			Yes	3	0	0	0
TP-9	10/24/2011	Oct.	2011	729852	3846815	0.86			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	729788	3846815	0.91			Yes	2	0	0	0
TP-9	10/24/2011	Oct.	2011	729786	3846788				No	0	0	0	0
TP-9	10/24/2011	Oct.	2011	729700	3846815	0.86			No	0	0	0	0
TP-9	10/24/2011	Oct.	2011	729655	3846815	0.30			Yes	0	2	0	0
TP-9	10/24/2011	Oct.	2011	729652	3846815	0.61			No	0	0	0	0
TP-9	10/24/2011	Oct.	2011	729650	3846815	0.23			Yes	0	2	0	0
TP-9	10/24/2011	Oct.	2011	729646	3846815	0.15			Yes	0	1	0	0
TP-3	01/31/2012	Jan.	2012	727328	3856241	0.3			No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727331	3856241	0.9			No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727336	3856240	1.7			No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727343	3856240	1.8			No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727374	3856239	0.5			No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727404	3856239		105.0		No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727435	3856238		40.3		No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727465	3856237		37.2		No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727503	3856237		42.0		No	0	0	0	0
TP-3	01/31/2012	Jan.	2012	727597	3856236		45.2		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726407	3854540		21.2		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726413	3854540		19.1		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726419	3854540		20.7		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726437	3854550		23.2		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726468	3854560		18.2		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726498	3854570		16.5		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726529	3854580	0.35	16.2		Yes	0	1	0	0
TP-2	01/31/2012	Jan.	2012	726559	3854590	0.39	26.3		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726590	3854609		29.2		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726605	3854700		50.6		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726813	3854722	0.76	43.8		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726825	3854722	0.3	53.6		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726837	3854722	0.49	75.1		No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-2	01/31/2012	Jan.	2012	726859	3854722		59.5		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726904	3854722	0.46	69.8		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	726950	3854722	0.40	67.4		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727026	3854722	0.31	71.0		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727103	3854722	0.30	71.4		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012			0.30	113.0		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012			0.30	89.3		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012			0.30	111.0		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727477	3854797	0.15			No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727571	3854834	0.38	98.0		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727664	3854871		98.3		No	0	0	0	0
TP-2	01/31/2012	Jan.	2012	727901	3854904	0.41	70.9		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726021	3853617	0.58	47.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726036	3853617		41.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726051	3853617		39.7		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726106	3853617	0.55	40.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726179	3853610	0.40	62.5		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726251	3853605	0.49	55.5		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726324	3853600	0.49	49.9		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726397	3853595	0.46	57.8		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726469	3853590		55.5		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726542	3853585	0.49	53.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726614	3853580	0.58	54.2		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726687	3853575	0.67	45.4		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726760	3853570	0.67	51.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726832	3853565	0.55	44.8		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726892	3853560	0.46	41.7		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726935	3853560	0.30	54.4		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	726966	3853560	0.24	73.7		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727066	3853560	0.30	77.8		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727167	3853560	0.52	65.8		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727268	3853560	0.91	58.5		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727368	3853560	0.91	44.6		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727469	3853560	0.88	46.6		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727569	3853560	0.82	67.4		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727670	3853560	0.88	63.1		No	0	0	0	0
TP-1	01/31/2012	Jan.	2012	727997	3853592	0.58	38.8		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	726877	3850928	1.19	66.1		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	726889	3850938		68.4		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	726901	3850948		53.4		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	726926	3850969	0.91	63.2		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	726950	3850989	0.70	66.3		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	727090	3851105	0.52	87.3		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	727229	3851222	0.49	67.6		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	727369	3851338	0.52	63.6		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	727509	3851454	0.30	52.2		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	727649	3851571	0.30	67.2		Yes	0	1	0	0
TP-6	01/31/2012	Jan.	2012	727788	3851687	0.61	52.2		No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbitity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	01/31/2012	Jan.	2012	727928	3851804	0.23	57.9		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728067	3851920	0.58	68.5		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728207	3851984	0.52	108.0		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728347	3851984	0.73	95.5		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728486	3851984	1.01	84.4		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728494	3851984	0.82	107.0		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728499	3851984	0.55	68.8		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728506	3851984	0.46	76.6		No	0	0	0	0
TP-6	01/31/2012	Jan.	2012	728568	3851984	0.46			Yes	0	1	0	0
TP-1	03/07/2012	Mar.	2012	726106	3853617	1.37	111.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726112	3853616	1.37			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726121	3853615	1.04			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726136	3853613	0.79			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726152	3853611	0.76			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726167	3853609	0.76	92.1		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726300	3853593	0.74			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726432	3853576	0.81			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726565	3853560	0.89	71.6		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726698	3853543	0.86			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726831	3853526	0.86	137.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	726964	3853510	0.86	111.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727097	3853493	0.61			Yes	0	1	0	0
TP-1	03/07/2012	Mar.	2012	727229	3853477	0.76	109.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727362	3853460	0.86	121.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727495	3853443	1.09			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727628	3853427	1.22			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727761	3853410	1.22	97.0		No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	727893	3853394	1.12			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	728026	3853377	1.07			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	728041	3853375	0.97			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	728041	3853374	0.46			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	728041	3853373	0.41			No	0	0	0	0
TP-1	03/07/2012	Mar.	2012	728042	3853377	0.15	137.0		No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728524	3848098	0.76–0.91			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728554	3848107	1.63			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728585	3848115	1.88			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728615	3848124	2.01			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728755	3848164	1.98			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	728894	3848204	1.96	50.0		No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	729033	3848244	1.96			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	729173	3848283	1.65			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	729312	3848323	1.42			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	729452	3848363	0.97			No	0	0	0	0
TP-5	03/07/2012	Mar.	2012	729497	3848404	0.30	67.5		No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	726842	3850960	0.76			Yes	0	1	0	0
TP-6	03/07/2012	Mar.	2012	726872	3850963	1.07			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	726903	3850966	0.97			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727055	3850969	1.07			No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	03/07/2012	Mar.	2012	727208	3850972	1.07	52.0		No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727574	3850975	0.91			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727630	3850978	0.94	60.2		No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727686	3850981	1.07			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727742	3850984	1.22			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727798	3850987	0.91			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727855	3850990	1.04			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727911	3850993		61.1		No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	727967	3850996	1.22			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728024	3850999	1.27			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728080	3851002	1.17	59.1		No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728136	3851005				No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728193	3851008	1.27			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728305	3851009	1.57			No	0	0	0	0
TP-6	03/07/2012	Mar.	2012	728457	3851009	0.46			No	0	0	0	0
TP-3	07/22/2013	July	2013	727313	3856304	0.58	43.0		Yes	1	0	0	0
TP-3	07/22/2013	July	2013	727316	3856307				Yes	1	0	0	0
TP-3	07/22/2013	July	2013	727318	3856317	1.18	32.7		Yes	1	0	0	0
TP-3	07/22/2013	July	2013	727331	3856327	2.93	31.4		No	0	0	0	0
TP-3	07/22/2013	July	2013	727370	3856337	1.28	38.7		No	0	0	0	0
TP-3	07/22/2013	July	2013	727410	3856360	1.13	31.5		No	0	0	0	0
TP-3	07/22/2013	July	2013	727440	3856347	1.24	30.8		No	0	0	0	0
TP-3	07/22/2013	July	2013	727454	3856350	1.25	30.5		No	0	0	0	0
TP-3	07/22/2013	July	2013	727483	3856357	1.70	29.6		No	0	0	0	0
TP-3	07/22/2013	July	2013	727503	3856375	1.40	32.1		No	0	0	0	0
TP-3	07/22/2013	July	2013	727527	3856387				Yes	1	0	0	0
TP-3	07/22/2013	July	2013	727552	3856396	1.20	34.1		Yes	3	1	0	0
TP-3	07/22/2013	July	2013	727557	3856397	1.00	26.0		Yes	3	0	0	0
TP-2	07/22/2013	July	2013	726388	3854522	1.20	14.2		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	726391	3854522	1.45	14.5		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	726393	3854522	1.65	16.9		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	726403	3854522	2.80	13.6		No	0	0	0	0
TP-2	07/22/2013	July	2013	726425	3854520	2.99	15.7		No	0	0	0	0
TP-2	07/22/2013	July	2013			0.40			No	0	0	0	0
TP-2	07/22/2013	July	2013	726477	3854538	0.94	19.3		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	726520	3854535	0.94	21.5		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	726563	3854535	1.04	19.4		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	726606	3854535	1.01	25.3		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	726648	3854535	1.07	26.1		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	726691	3854535	1.04			Yes	1	0	0	0
TP-2	07/22/2013	July	2013	726734	3854535	1.01	22.4		No	0	0	0	0
TP-2	07/22/2013	July	2013	726753	3854525	0.95	22.2		Yes	0	1	0	1
TP-2	07/22/2013	July	2013	727295	3854535	0.31	16.1		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	727304	3854545	0.31	22.1		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	727325	3854555	0.91	29.3		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	727345	3854565	0.94	25.1		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	727395	3854585	1.20	37.2		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	727445	3854605	1.30	44.8		Yes	1	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-2	07/22/2013	July	2013	727688	3854618	1.30	40.1		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	727805	3854682	1.80	43.9		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	728002	3854695	1.58	41.3		Yes	1	0	0	0
TP-2	07/22/2013	July	2013	728002	3854708	0.50	29.4		No	0	0	0	0
TP-2	07/22/2013	July	2013	728002	3854721	0.40	30.1		Yes	1	1	0	0
TP-2	07/22/2013	July	2013	728002	3857743	0.40	70.4		No	0	0	0	0
TP-1	07/22/2013	July	2013	728015	3853566	0.68	41.0		Yes	1	1	0	0
TP-1	07/22/2013	July	2013	728012	3853566	0.76	37.1		Yes	1	0	0	0
TP-1	07/22/2013	July	2013	728010	3853566	0.80	34.1		Yes	1	1	0	0
TP-1	07/22/2013	July	2013	728000	3853566	1.52	48.3		Yes	1	0	0	0
TP-1	07/22/2013	July	2013	727985	3853566	1.55	49.0		No	0	0	0	0
TP-1	07/22/2013	July	2013	727924	3853569	1.49	56.3		No	0	0	0	0
TP-1	07/22/2013	July	2013	727724	3853580	1.34	50.4		Yes	1	0	0	0
TP-1	07/22/2013	July	2013	727577	3853593	1.25	44.2		No	0	0	0	0
TP-1	07/22/2013	July	2013	727477	3853601	1.19	44.2		Yes	2	0	0	0
TP-1	07/22/2013	July	2013	727349	3853611	1.15	43.5		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	727274	3853621	1.13	41.6		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	727199	3853631	1.03	37.7		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	727124	3853641	1.03	29.6		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	727028	3853564	1.10	56.5		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	726516	3853570	0.82	59.6		Yes	3	0	0	0
TP-1	07/22/2013	July	2013	727516	3853577	1.30	91.1		Yes	2	0	0	1
TP-1	07/22/2013	July	2013	726345	3853606	1.20	79.1		Yes	1	1	0	2
TP-1	07/22/2013	July	2013	726175	3853609	1.15	76.4		No	0	0	0	0
TP-1	07/22/2013	July	2013	726070	3853600	1.31	77.8		Yes	0	0	0	1
TP-1	07/22/2013	July	2013	726025	3853597	1.70	36.4		No	0	0	0	0
TP-1	07/22/2013	July	2013	726023	3853590	1.35	30.6		No	0	0	0	0
TP-1	07/22/2013	July	2013	726020	3853587	1.00	28.5		No	0	0	0	0
TP-6	07/23/2013	July	2013	726826	3850981	0.75	11.6		Yes	0	1	0	0
TP-6	07/23/2013	July	2013	726829	3850988	0.81	11.8		Yes	0	1	0	0
TP-6	07/23/2013	July	2013	726831	3851002	0.80	8.4		Yes	0	2	0	0
TP-6	07/23/2013	July	2013	726841	3851016	1.95	11.1		Yes	0	1	0	0
TP-6	07/23/2013	July	2013	726856	3851030	1.20	10.7		No	0	0	0	0
TP-6	07/23/2013	July	2013	726866	3851044	1.30	14.8		No	0	0	0	0
TP-6	07/23/2013	July	2013	726815	3851045				No	0	0	0	0
TP-6	07/23/2013	July	2013	726865	3851042	1.22	12.4		No	0	0	0	0
TP-6	07/23/2013	July	2013	726934	3851042	1.24	12.2		No	0	0	0	0
TP-6	07/23/2013	July	2013	727033	3851111	0.74	6.4		Yes	1	1	0	0
TP-6	07/23/2013	July	2013	727063	3851111	0.79	8.8		Yes	1	1	0	0
TP-6	07/23/2013	July	2013	727093	3851111	1.10	22.2		Yes	1	0	0	0
TP-6	07/23/2013	July	2013	727106	3851111	1.19	26.2		Yes	0	1	0	0
TP-6	07/23/2013	July	2013	727206	3851150	1.20	27.5	41	Yes	0	1	0	0
TP-6	07/23/2013	July	2013	727308	3851191	1.20	29.0	41	No	0	0	0	0
TP-6	07/23/2013	July	2013	727408	3851200	1.10	26.6		Yes	1	0	0	0
TP-6	07/23/2013	July	2013	727509	3851233	1.30	31.3	38	Yes	1	1	0	0
TP-6	07/23/2013	July	2013	727520	3851240	1.40	31.5		Yes	1	1	0	0
TP-6	07/23/2013	July	2013	727539	3851248	1.25	34.1		Yes	2	1	1	0
TP-6	07/23/2013	July	2013	727739	3851208	1.60	33.6	40	Yes	1	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	07/23/2013	July	2013	727939	3851168	1.30	37.2		Yes	0	1	0	0
TP-6	07/23/2013	July	2013	728176	3851115	1.20	25.5	48	Yes	0	1	0	0
TP-6	07/23/2013	July	2013	728251	3851110	1.65	35.5		No	0	0	0	0
TP-6	07/23/2013	July	2013	728326	3851100	1.35			No	0	0	0	0
TP-6	07/23/2013	July	2013	728401	3851085	1.15	36.4	37	Yes	0	1	0	0
TP-6	07/23/2013	July	2013	728471	3851077	0.80	41.2		No	0	0	0	0
TP-8	07/23/2013	July	2013	730428	3846946	0.30	28.2		Yes	0	0	2	0
TP-8	07/23/2013	July	2013	730378	3846976	0.58	24.9		Yes	0	1	1	0
TP-8	07/23/2013	July	2013	730328	3847006	1.60	25.2	42	No	0	0	0	0
TP-8	07/23/2013	July	2013	730275	3847022	1.84	28.9	39	No	0	0	0	0
TP-8	07/23/2013	July	2013	730125	3847122	1.95	28.3		No	0	0	0	0
TP-8	07/23/2013	July	2013	729909	3847203	2.10	29.5		No	0	0	0	0
TP-8	07/23/2013	July	2013	729739	3847263	2.01	35.5	30	No	0	0	0	0
TP-8	07/23/2013	July	2013	729579	3847320	2.10	44.0	39	No	0	0	0	0
TP-8	07/23/2013	July	2013	729479	3847365	2.19	48.7	31	No	0	0	0	0
TP-8	07/23/2013	July	2013	729378	3847392	2.29	35.1	31	No	0	0	0	0
TP-8	07/23/2013	July	2013	729303	3847402	2.26	25.4	36	No	0	0	0	0
TP-8	07/23/2013	July	2013	729228	3847412	0.87	25.3		Yes	0	0	2	0
TP-8	07/23/2013	July	2013	729153	3847422	0.87	25.1	38	Yes	0	0	2	0
TP-8	07/23/2013	July	2013	729148	3847427	0.85	24.7		Yes	0	0	2	0
TP-5	07/23/2013	July	2013	729464	3848649	0.72	13.5	58	Yes	0	1	0	0
TP-5	07/23/2013	July	2013	729429	3848642	0.90	13.6		Yes	0	1	0	0
TP-5	07/23/2013	July	2013	729394	3848632	1.82	14.6	52	No	0	0	0	0
TP-5	07/23/2013	July	2013	729357	3848622	1.95	15.9		No	0	0	0	0
TP-5	07/23/2013	July	2013	729231	3848600	2.41	14.9	54	No	0	0	0	0
TP-5	07/23/2013	July	2013	729131	3848572	2.35	15.7	55	No	0	0	0	0
TP-5	07/23/2013	July	2013	728942	3848549	2.26	16.5		No	0	0	0	0
TP-5	07/23/2013	July	2013	728792	3848529	2.19	16.8		No	0	0	0	0
TP-5	07/23/2013	July	2013	728584	3848500	2.04	18.8		No	0	0	0	0
TP-5	07/23/2013	July	2013	728434	3848473	1.90	17.6	54	No	0	0	0	0
TP-5	07/23/2013	July	2013	728387	3848470	0.95	14.5	57	Yes	0	1	0	0
TP-5	07/23/2013	July	2013	728317	3848470	0.85			No	0	0	0	0
TP-5	07/23/2013	July	2013	728311	3848470	0.82	12.0		No	0	0	0	0
TP-5	07/23/2013	July	2013	728297	3848473	0.73	11.3		No	0	0	0	0
TP-5	07/23/2013	July	2013	728295	3848473	0.70	19.7		Yes	0	1	0	0
TP-5	07/23/2013	July	2013	728292	3848479	0.42	10.8	42	No	0	0	0	0
TP-3	10/29/2013	Oct.	2013	727309	3856304	0.00			No	0	0	0	0
TP-3	10/29/2013	Oct.	2013	727310	3856304	0.25			Yes	1	1	0	0
TP-3	10/29/2013	Oct.	2013	727312	3856304	0.60	21.8		Yes	2	1	0	0
TP-3	10/29/2013	Oct.	2013	727313	3856304	0.80	24.0		Yes	3	0	0	0
TP-3	10/29/2013	Oct.	2013	727319	3856300	2.19	22.1		No	0	0	0	0
TP-3	10/29/2013	Oct.	2013	727351	3856315	2.68	19.3		No	0	0	0	0
TP-3	10/29/2013	Oct.	2013	727382	3856328	1.20	14.0		Yes	2	1	0	0
TP-3	10/29/2013	Oct.	2013	727411	3856336	1.90	13.9		Yes	3	1	3	0
TP-3	10/29/2013	Oct.	2013	727425	3856343	0.91	4.3		Yes	3	1	2	0
TP-3	10/29/2013	Oct.	2013	727459	3856355	1.20	7.8	120	Yes	3	1	0	0
TP-3	10/29/2013	Oct.	2013	727496	3856359	1.50	5.5		Yes	3	1	0	0
TP-3	10/29/2013	Oct.	2013	727525	3856362	1.10	3.6		Yes	3	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014. —Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-3	10/29/2013	Oct.	2013	727553	3856368	0.85	7.7		Yes	3	2	0	0
TP-3	10/29/2013	Oct.	2013	727558	3856368	0.90	5.4		Yes	3	0	0	0
TP-3	10/29/2013	Oct.	2013	727561	3856369	0.70	8.6		Yes	3	0	0	0
TP-3	10/29/2013	Oct.	2013	727562	3856369	0.70			Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	726389	3854527	1.00	16.6		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	726412	3854538	2.56	15.9		No	0	0	0	0
TP-2	10/29/2013	Oct.	2013	726477	3854539	0.76	25.6		Yes	2	1	0	1
TP-2	10/29/2013	Oct.	2013	726501	3854547	0.90	52.9		Yes	2	2	0	0
TP-2	10/29/2013	Oct.	2013	726544	3854545	0.79	38.8		Yes	3	1	0	0
TP-2	10/29/2013	Oct.	2013	726583	3854549	0.80	23.0		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013			0.85	21.8		Yes	3	1	0	0
TP-2	10/29/2013	Oct.	2013			0.90	22.5		Yes	2	1	0	0
TP-2	10/29/2013	Oct.	2013	726726	3854553	0.85	22.5		Yes	3	1	1	0
TP-2	10/29/2013	Oct.	2013	726740	3854554	0.80	14.5		Yes	3	1	1	2
TP-2	10/29/2013	Oct.	2013			0.80	14.5		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	726998	3854524	0.65	16.3		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727084	3854515	0.87	14.5		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727169	3854528	0.74	11.3		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727274	3854532	0.88	7.6		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727423	3854573	0.80	19.1		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	727561	3854572	1.00	36.1		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	727620	3854560	0.58	16.2		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727800	3854586	0.70	27.0		Yes	3	0	0	0
TP-2	10/29/2013	Oct.	2013	727909	3854598	0.90	74.4		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	728026	3854590	0.95	95.4		Yes	2	0	0	0
TP-2	10/29/2013	Oct.	2013	728093	3854593	0.85	63.3		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727994	3853671	0.73	17.4		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727918	3853641	1.28	33.3		Yes	1	0	0	0
TP-1	10/29/2013	Oct.	2013	727804	3853631	1.13	38.8	34	Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727674	3853628	0.85	29.4		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727505	3853637	0.76	17.5	52	Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727309	3853633	0.95	29.5		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727098	3853600	0.90	30.5		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	727008	3853584	0.75	15.4		Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	726869	3853556	1.00	35.6	46	Yes	2	0	0	0
TP-1	10/29/2013	Oct.	2013	726746	3853585	1.15	43.5		Yes	2	0	0	1
TP-1	10/29/2013	Oct.	2013	726559	3853600	1.10	52.1		Yes	2	0	0	1
TP-1	10/29/2013	Oct.	2013	726404	3853623	1.05	62.1		Yes	2	0	0	1
TP-1	10/29/2013	Oct.	2013	726184	3853640	0.96	71.2		Yes	2	0	0	2
TP-1	10/29/2013	Oct.	2013	726063	3853599	1.10	21.7		Yes	2	0	0	2
TP-1	10/29/2013	Oct.	2013	726020	3853585	1.22	15.7	64	Yes	2	0	0	0
TP-8	10/30/2013	Oct.	2013	N/A	N/A	0.20	242.0		Yes	1	0	0	0
TP-8	10/30/2013	Oct.	2013	730433	3846923	0.30		18	Yes	1	1	1	0
TP-8	10/30/2013	Oct.	2013	730430	3846923	0.55	111.0	13	Yes	2	1	0	0
TP-8	10/30/2013	Oct.	2013	730417	3846920	1.20	114.0		No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	730374	3846942	1.20	113.0		Yes	1	0	0	0
TP-8	10/30/2013	Oct.	2013	730315	3846952	1.48	128.0	21	No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	730223	3846974	1.65	123.0	20	No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

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				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-8	10/30/2013	Oct.	2013	730078	3846998	1.87	110.0		No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729885	3847035	1.95	125.0		No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729689	3847077	1.20	122.0	17	Yes	1	0	0	0
TP-8	10/30/2013	Oct.	2013	729585	3847114	1.54	160.0	12	No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729508	3847136	1.92	144.0	14	No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729461	3847142	1.95	147.0	13	No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729405	3847144	1.83	164.0		Yes	0	1	0	0
TP-8	10/30/2013	Oct.	2013	729368	3847150	1.10	167.0		Yes	1	0	0	0
TP-8	10/30/2013	Oct.	2013	729360	3847148	0.54	127.0	17	No	0	0	0	0
TP-8	10/30/2013	Oct.	2013	729355	3847143	0.48	148.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	729467	3848641	0.30		26	No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	729461	3848640	0.50	63.0		Yes	0	1	0	0
TP-5	10/30/2013	Oct.	2013	729450	3848637	1.10	56.0	29	No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	729428	3848635	1.69	59.0	27	Yes	1	0	0	0
TP-5	10/30/2013	Oct.	2013	729357	3848623	1.80	61.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	729288	3848600	1.90	62.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	729213	3848555	2.13	66.0		Yes	1	0	0	0
TP-5	10/30/2013	Oct.	2013	729086	3848551	2.10	63.0		Yes	1	0	0	0
TP-5	10/30/2013	Oct.	2013	728955	3848584	1.98	61.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	728814	3848496	1.95	63.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	728687	3848404	1.89	65.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	728602	3848338	1.65	68.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	728495	3848264	1.83	70.0		No	0	0	0	0
TP-5	10/30/2013	Oct.	2013	728445	3848244	1.20	64.0		Yes	2	0	0	0
TP-5	10/30/2013	Oct.	2013	728395	3848212	0.50	68.0		Yes	3	0	1	0
TP-6	10/30/2013	Oct.	2013	728472	3851076	0.00			No	0	0	0	0
TP-6	10/30/2013	Oct.	2013	728474	3851075	0.60	74.0		Yes	1	0	0	0
TP-6	10/30/2013	Oct.	2013	728471	3851078	1.10	70.0		Yes	2	1	0	0
TP-6	10/30/2013	Oct.	2013	728447	3851074	1.52	72.0		Yes	1	0	0	0
TP-6	10/30/2013	Oct.	2013	728381	3851097	1.68	74.0		Yes	1	0	0	0
TP-6	10/30/2013	Oct.	2013	728281	3851130	1.10	59.0		Yes	3	1	0	0
TP-6	10/30/2013	Oct.	2013	728240	3851115	1.10	54.0		Yes	3	1	0	0
TP-6	10/30/2013	Oct.	2013	728188	3851114	0.99	59.0		Yes	3	0	0	0
TP-6	10/30/2013	Oct.	2013	728149	3851100	1.20	66.0		Yes	1	1	0	0
TP-6	10/30/2013	Oct.	2013	728101	3851134	1.48	68.0		Yes	1	0	0	0
TP-6	10/30/2013	Oct.	2013	727939	3851214	1.10	47.0		Yes	2	2	1	0
TP-6	10/30/2013	Oct.	2013	727850	3851168	1.00	41.0	33	Yes	3	1	1	0
TP-6	10/30/2013	Oct.	2013	727784	3851206				No	0	0	0	0
TP-6	10/30/2013	Oct.	2013	727649	3851201	1.20	58.0		Yes	3	0	0	0
TP-6	10/30/2013	Oct.	2013	727524	3851233	1.02	19.0		Yes	2	1	0	0
TP-6	10/30/2013	Oct.	2013	727443	3851241	1.00	15.0		Yes	3	0	0	0
TP-6	10/30/2013	Oct.	2013	727395	3851244	0.80	7.0		Yes	3	0	0	0
TP-6	10/30/2013	Oct.	2013	727384	3851240	0.82	8.0		Yes	3	0	0	0
TP-6	10/30/2013	Oct.	2013	727234	3851200				No	0	0	0	0
TP-6	10/30/2013	Oct.	2013	727034	3851113	0.55	3.0		Yes	2	1	1	0
TP-6	10/30/2013	Oct.	2013	726955	3851020	0.90	8.0		Yes	2	0	0	0
TP-6	10/30/2013	Oct.	2013	726914	3850993	1.30	9.0		Yes	2	0	0	0
TP-6	10/30/2013	Oct.	2013	726894	3850988	1.04	11.0		Yes	2	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

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				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	10/30/2013	Oct.	2013	726874	3850968	0.61	13.0		Yes	1	1	0	0
TP-6	10/30/2013	Oct.	2013	726853	3850948	0.00			No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	N/A	N/A	1.60	35.8		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	N/A	N/A	1.20	38.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	N/A	N/A	1.00	32.7		Yes	0	0	0	1
TP-1	10/03/2014	Oct.	2014	726101	3853642	1.00	31.5		Yes	0	0	0	1
TP-1	10/03/2014	Oct.	2014	726137	3853661	1.00	32.5		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726160	3853669	1.00	34.0		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726189	3853666	1.00	32.9		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726201	3853653	1.00	34.9		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014			1.10	58.5		Yes	0	0	0	1
TP-1	10/03/2014	Oct.	2014			1.10	49.7		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014			1.00	60.3		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014			1.00	59.2		Yes	0	0	0	3
TP-1	10/03/2014	Oct.	2014			1.00	63.0		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014			1.00	66.0		Yes	0	0	0	3
TP-1	10/03/2014	Oct.	2014			1.00	69.8		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726411	3853617	1.00	89.0		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726433	3853607	1.00	80.8		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726454	3853599	1.00	84.5		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726488	3853604	1.00	97.5		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726531	3853610	1.00	101.0		Yes	0	0	0	1
TP-1	10/03/2014	Oct.	2014	726552	3853607	1.00	104.0		Yes	0	0	0	1
TP-1	10/03/2014	Oct.	2014	726570	3853599	1.00	104.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726586	3853588	1.15	97.3		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726661	3853578	1.00	99.9		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726736	3853568	1.00	93.5		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726758	3853565	1.00	94.8		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726844	3853603	1.05	98.4		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726845	3853557	1.00	104.0		Yes	0	0	0	2
TP-1	10/03/2014	Oct.	2014	726895	3853550	0.95	105.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	726945	3853540	0.80	106.0		Yes	2	0	0	0
TP-1	10/03/2014	Oct.	2014	726987	3853535	0.80	102.0		Yes	1	0	0	0
TP-1	10/03/2014	Oct.	2014	727083	3853592	0.80	100.0		Yes	1	0	0	0
TP-1	10/03/2014	Oct.	2014	727083	3853596	0.80	100.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727212	3853712	0.85	102.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727158	3853590	0.80	106.0		Yes	1	0	0	0
TP-1	10/03/2014	Oct.	2014	727158	3853590	0.80	104.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727237	3853392	0.85	111.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727324	3853576	0.90	114.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727400	3853558	1.05	113.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727469	3853539	1.15	116.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727571	3853533	1.25	119.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727593	3853501	1.30	118.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727686	3853474	1.35	124.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727686	3853460	1.45	128.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727797	3853511	1.40	126.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727849	3853536	1.45	129.0		No	0	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbidity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-1	10/03/2014	Oct.	2014	727908	3853560	1.40	119.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727986	3853563	1.50	124.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014	727998	3853573	1.40	122.0		No	0	0	0	0
TP-1	10/03/2014	Oct.	2014			0.70	120.0		Yes	1	0	0	0
TP-6	10/03/2014	Oct.	2014			1.65	35.5		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726861	3851005	1.50	59.0		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726889	3851000	1.30	64.3		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726925	3850994	1.20	65.9		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726971	3850991	1.00	82.6		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	727013	3850994	1.05	85.9		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	727055	3850995	1.10	77.9		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	727098	3850994	1.10	82.1		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	727147	3850995	1.10	90.5		Yes	3	1	0	0
TP-6	10/03/2014	Oct.	2014	727211	3850988	1.10	91.2		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	727263	3850992	1.10	103.0		Yes	2	0	0	0
TP-6	10/03/2014	Oct.	2014	727328	3850994	1.10	104.0		Yes	1	0	0	0
TP-6	10/03/2014	Oct.	2014	727385	3851003	1.05	109.0		Yes	1	0	0	0
TP-6	10/03/2014	Oct.	2014	727428	3851003	1.05	117.0		Yes	1	0	0	0
TP-6	10/03/2014	Oct.	2014	727485	3851009	1.15	124.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727535	3851014	1.15	130.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727593	3851019	1.13	134.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727647	3851021	1.40	142.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727736	3851093	1.40	141.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727880	3851055	1.30	146.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727888	3851055	1.30	138.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	727971	3851061	1.65	137.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728036	3851078	1.50	148.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728089	3851090	1.50	146.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728143	3851108	1.35	130.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728233	3851116	1.15	114.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728287	3851122	1.20	118.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728338	3851127	1.50	119.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728386	3851128	1.80	121.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728422	3851132	1.80	101.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728463	3851141	1.20	65.0		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728485	3851151	0.30	80.7		No	0	0	0	0
TP-6	10/03/2014	Oct.	2014	728491	3851149	0.30	113.0	30	Yes	1	0	0	0
TP-6	10/03/2014	Oct.	2014	726796	3851017	1.60	35.0		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726773	3851024	1.55	44.3		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726746	3851033	1.50	51.3		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726717	3851043	1.50	51.3		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726693	3851051	1.50	56.1		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726641	3851065	1.50	56.5		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726579	3851075	1.50	63.6		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726523	3851074	1.50	57.0		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726465	3851059	1.50	49.1		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726411	3851055	1.20	54.5		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726377	3851057	1.20	62.9		Yes	3	0	0	0

Table 8. Submerged aquatic vegetation coverage ratings along east-west transects within Topock Marsh from July 2011 to October 2014.—Continued

[Data are presented in the order they were taken. Coverage ratings: 0 = no vegetation, 1 = <30% (low) vegetation coverage, 2 = 30%–<70% (moderate) coverage, and 3 = 70–100% (high) coverage. NAD 83: UTM – 11N, North American Datum of 1983 Universal Transverse Mercator - 11 degrees North; AdjEasting, adjusted easting units; m, meter; AdjNorthing, adjusted northing units; NTU, nephelometric turbidity unit; cm, centimeter; SAV submerged aquatic vegetation; TP, sampling station; N/A, not applicable]

				NAD 83: UTM - 11N						Coverage			
Transect name	Date	Month	Year	AdjEasting (m)	AdjNorthing (m)	Water depth (m)	Turbitity (NTUs)	Secchi depth (cm)	SAV present	Spiny naiad[2]	Sago pond-weed[2]	Chara[2]	Eurasian water-milfoil[2]
TP-6	10/03/2014	Oct.	2014	726353	3851057	1.40	50.7		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726326	3851059	1.20	51.7		Yes	3	0	0	0
TP-6	10/03/2014	Oct.	2014	726312	3851061	0.50	36.7		Yes	3	0	0	0
TP-9	10/06/2014	Oct.	2014	730458	3846839	0.20			No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			0.37	87.2		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			0.66	95.0		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.02	85.7		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.35	94.6		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.80	79.5		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.62	78.6		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.60	84.9		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014	729972	3846791	1.70	72.8		Yes	1	0	0	0
TP-9	10/06/2014	Oct.	2014	730219	3846850	1.58	68.7		Yes	0	1	0	0
TP-9	10/06/2014	Oct.	2014			1.28	70.4		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014			1.00	71.6		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014	729665	3846804	0.72	74.0		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014	729624	3846842	0.45	74.0		No	0	0	0	0
TP-9	10/06/2014	Oct.	2014	729568	3846845	0.30	68.2		Yes	1	0	0	0
TP-9	10/06/2014	Oct.	2014	729542	3846861	0.45	69.2		Yes	2	0	0	0
TP-9	10/06/2014	Oct.	2014	729526	3846876	0.28	70.2		Yes	2	1	0	0
TP-3	10/07/2014	Oct.	2014	727330	3856126	0.60	47.1		Yes	3	1	0	0
TP-3	10/07/2014	Oct.	2014	727331	3856125	0.87	43.3		Yes	2	0	0	0
TP-3	10/07/2014	Oct.	2014	727361	3856118	>2.00	37.6		No	0	0	0	0
TP-3	10/07/2014	Oct.	2014	727412	3856126	0.99	46.5		Yes	0	0	1	0
TP-3	10/07/2014	Oct.	2014	727431	3856153	1.00	54.6		Yes	1	0	1	0
TP-3	10/07/2014	Oct.	2014	727468	3856161	0.99	44.7		Yes	0	1	0	0
TP-3	10/07/2014	Oct.	2014	727513	3856160	1.33	40.1		Yes	1	0	0	0
TP-3	10/07/2014	Oct.	2014	727536	3856159	1.28	36.6		No	0	0	0	0
TP-3	10/07/2014	Oct.	2014	727569	3856154	1.07	45.1		Yes	3	0	0	0
TP-3	10/07/2014	Oct.	2014	727571	3856155	0.98	46.7		Yes	2	0	0	0
TP-3	10/07/2014	Oct.	2014	727584	3856196	0.81	25.0		Yes	3	0	0	0

[1]Some GPS Easting and Northing units were adjusted/corrected according to handwritten field notes. Therefore, coordinates are not precise locations but are best estimates.

[2]Spiny naiad = *Najas marina*, Sago pondweed = *Stuckenia pectinata*, Chara = *Chara* sp., and Eurasian watermilfoil = *Myriophyllum spicatum*.

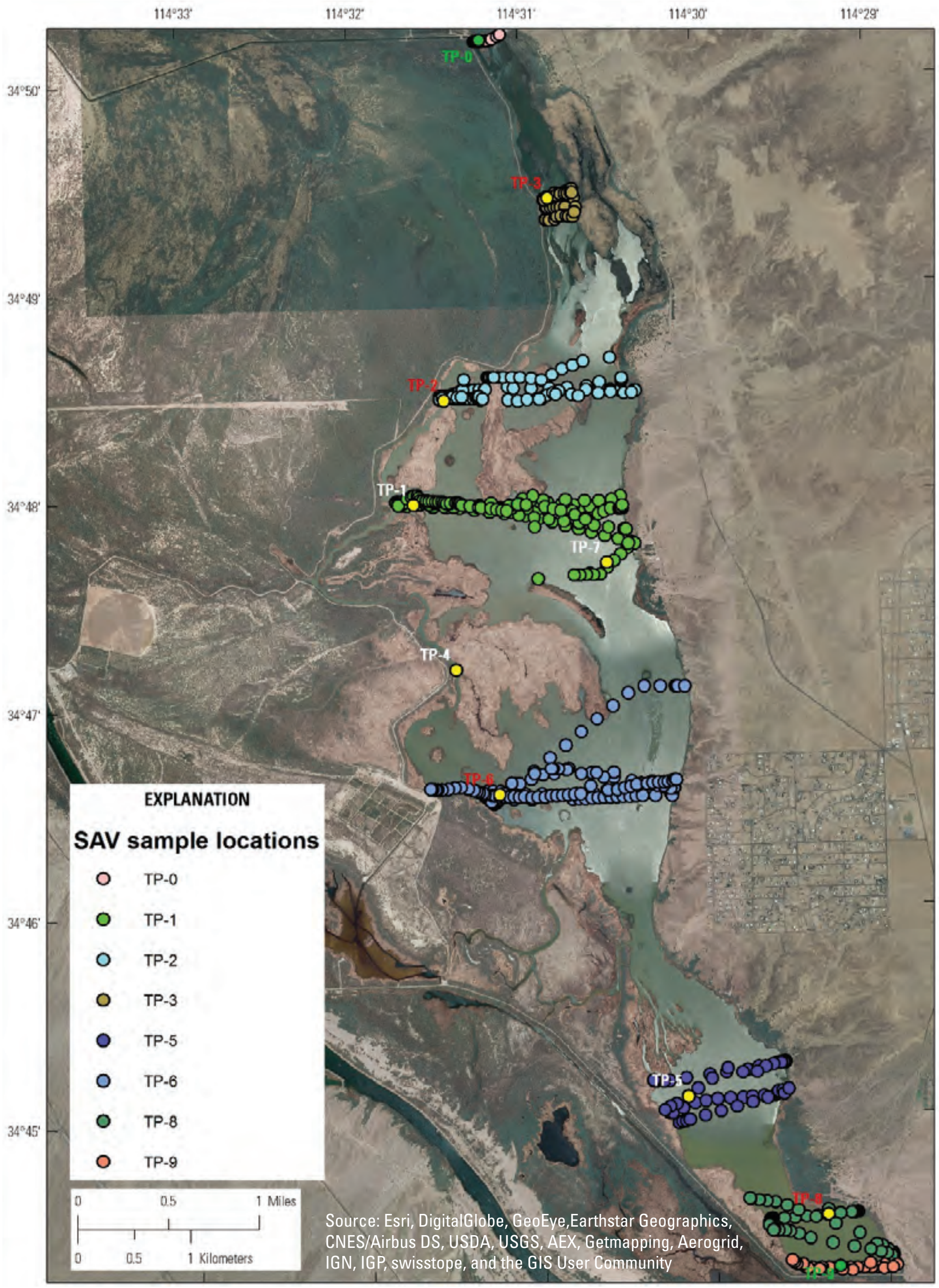

Figure 21. Submerged aquatic vegetation (SAV) sampling from July 2011 to October 2014 along transects within Topock Marsh, Arizona. (TP, sampling station).

Table 9. Submerged aquatic vegetation presence ratios by sampling transect within Topock Marsh from October 2011 to October 2014.

[No., number; TP, sampling site]

Transect	Year	Month	No. of sampling points along the transect	Spiny naiad[1]	Sago pondweed[1]	Chara[1]	Eurasian watermilfoil[1]
TP-0	2011	Oct.	13	1.00	0.08	0.00	0.00
TP-1	2011	Sept.	17	0.24	0.35	0.00	0.00
TP-1	2011	Oct.	29	0.21	0.07	0.00	0.00
TP-1	2012	Jan.	25	0.00	0.00	0.00	0.00
TP-1	2012	Mar.	24	0.00	0.04	0.00	0.00
TP-1	2013	July	22	0.64	0.14	0.00	0.14
TP-1	2013	Oct.	15	1.00	0.00	0.00	0.33
TP-1	2014	Oct.	50	0.10	0.00	0.00	0.32
TP-2	2011	Sept.	22	0.05	0.18	0.00	0.00
TP-2	2012	Jan.	25	0.00	0.04	0.00	0.00
TP-2	2013	July	26	0.73	0.35	0.00	0.04
TP-2	2013	Oct.	22	0.95	0.32	0.09	0.09
TP-3	2011	Sept.	16	0.63	0.13	0.06	0.00
TP-3	2012	Jan	10	0.00	0.00	0.00	0.00
TP-3	2013	July	13	0.46	0.08	0.00	0.00
TP-3	2013	Oct.	16	0.81	0.50	0.13	0.00
TP-3	2014	Oct.	11	0.64	0.18	0.18	0.00
TP-5	2011	Sept.	20	0.90	0.30	0.00	0.00
TP-5	2012	Mar	11	0.00	0.00	0.00	0.00
TP-5	2013	July	16	0.00	0.25	0.00	0.00
TP-5	2013	Oct.	15	0.33	0.07	0.07	0.00
TP-6	2011	July	10	0.90	0.00	0.00	0.00
TP-6	2011	Sept.	22	0.68	0.23	0.00	0.00
TP-6	2012	Jan	20	0.00	0.10	0.00	0.00
TP-6	2012	Mar	19	0.00	0.05	0.00	0.00
TP-6	2013	July	26	0.31	0.54	0.04	0.00
TP-6	2013	Oct.	25	0.84	0.36	0.12	0.00
TP-6	2014	Oct.	47	0.62	0.02	0.00	0.00
TP-8	2011	July	9	0.22	0.00	0.00	0.00
TP-8	2011	Sept.	22	0.91	0.41	0.00	0.00
TP-8	2013	July	14	0.00	0.07	0.36	0.00
TP-8	2013	Oct.	17	0.35	0.18	0.06	0.00
TP-9	2011	Oct.	21	0.57	0.33	0.05	0.00
TP-9	2014	Oct.	17	0.24	0.12	0.00	0.00
Total	--	--	**687**	--	--	--	--
Total mean	**2011–2014**	**All**	--	**0.42**	**0.17**	**0.04**	**0.03**

[1]Spiny naiad = *Najas marina*, Sago pondweed= *Stuckenia pectinata*, Chara = *Chara* sp., and Eurasian watermilfoil = *Myriophyllum spicatum*.

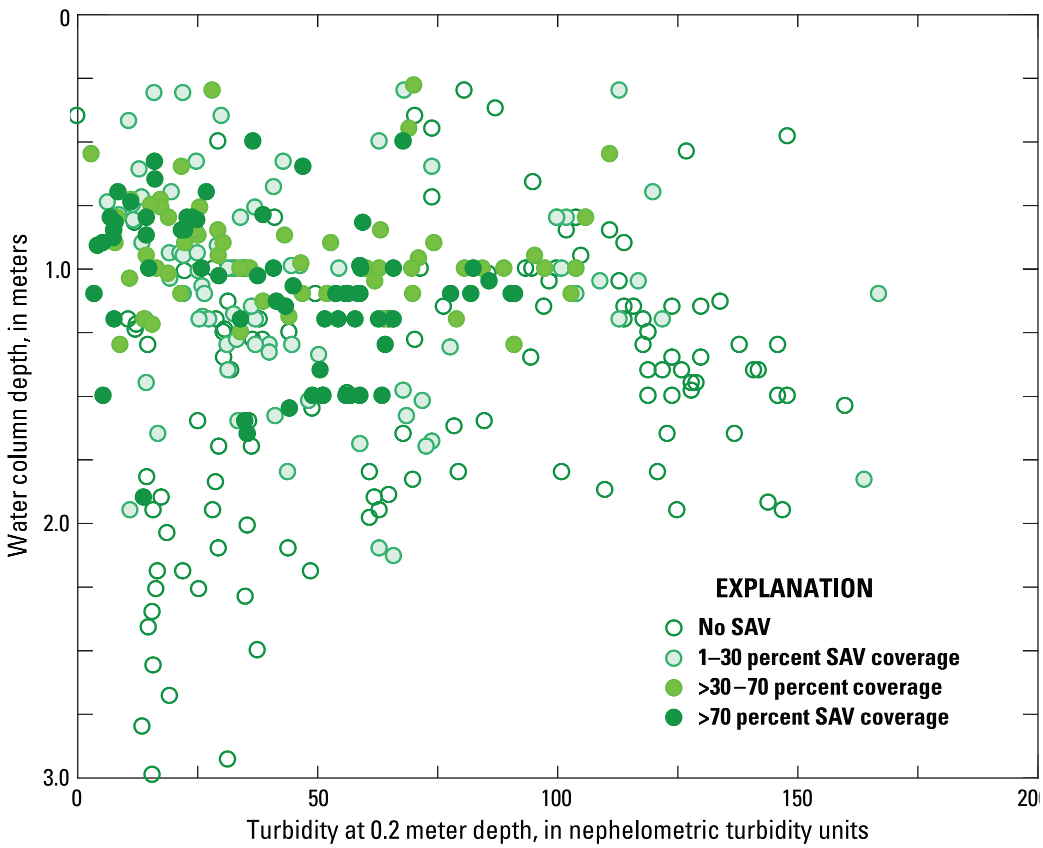

Figure 22. Scatterplot of coverage values for the submerged aquatic vegetation (SAV) in Topock Marsh, Arizona, during October 2011, October 2013, and October 2014 in relation to water depth and turbidity measurements for each observation point.

The next SAV survey was performed in July 2013 and spiny naiad coverage was recorded as low abundance to dense across the middle of the marsh (TP-1 transect), particularly in the more protected areas in water ≤1.3 m (≤4.3 ft) deep. However, similar to 2011, spiny naiad was much less abundant in open areas of the marsh even at shallow depths. Further downstream along TP-5 and TP-8 transects, spiny naiad was not observed (tables 8 and 9). Sago pondweed, on the other hand, was scarce along the transects, with most observations being a single plant near shore in ≤1.0 m (≤3.3 ft) water depth and fairly clear water. By October 2013, however, spiny naiad became more common and even abundant across the northern transects, but remained less frequent along TP-5 and TP-8. Sago pondweed became somewhat more abundant along TP-3, TP-2, and TP-6 transects, but was uncommon elsewhere. The pattern of density and abundance of spiny naiad and sago pondweed observed in October 2013 was seen again in October 2014 with the exception that Eurasian watermilfoil, not spiny naiad, was the dominant SAV species along the TP-1 transect (tables 8 and 9).

In July 2013, one rooted Eurasian watermilfoil plant was found on the TP-2 transect, and a few more rooted plants or clumps of plants were observed along the TP-1 transect (table 8). In October 2013, more plants were observed along the western portion of the TP-2 transect and along the TP-1 transect just east of the Glory Hole area (figs. 1 and 21). By October 2014, the invasive Eurasian watermilfoil was well established and thriving throughout the area east of the Glory Hole, forming large, thick mats flowering at the water surface (table 8).

Two chara plants (*Chara* sp., a macroalgae) were noted in 2011 in very shallow water. However, by July 2013, a few chara patches were growing along the eastern and western edges of TP-8 in 0.86 m (2.8 ft) water depths, in 0.75 m (2.5 ft) water depths along TP-5, and among a burreed (*Sparganium* sp.) stand growing along TP-6 in 1.25 m (4.1 ft) water depth with a turbidity of 34 NTUs (table 8). There were no flowers or other distinguishing features to identify the burreed, a macrophyte, to species. In October 2013, chara was seen growing among mesquite snags in clear water of 0.9–1.9 m (3.0–6.2 ft) water depths along TP-3, and in 0.85 m (2.8 ft) water depths along TP-2. Very few other chara plants were seen elsewhere in Topock Marsh (table 9).

The SAV coverage ratings (0, 1, 2, or 3) recorded along each transect were plotted in relation to water depth and surface turbidity measured at each observation point in October 2011, October 2013, and October 2014 (fig. 22). This scatterplot illustrates that the highest SAV coverage clusters were present at water depths of between 0.5 and 1.5 m (1.6 and 4.9 ft) and where surface turbidities were measured at ≤100 NTUs (fig. 22). Akaike's Information Criteria indicated that the best model to explain SAV coverage was the ANOVA of surface turbidity (as opposed to water depth). As turbidity increased, SAV decreased (ANOVA: F = 43.63, df = 3,1, $R^2 = 0.37$, $p = 0.007$). All pairwise comparison tests (that is, Tukey's Honest Significant Difference Test) were significantly different ($p < 0.01$), except for the comparisons of surface turbidity between SAV = 0 and SAV = 1, and between SAV = 2 and SAV = 3.

The SAV coverage ratings and their relationship to water depth along the east-west transects are not illustrated in this report; however, the 2011–12 data were illustrated in an administrative report we previously submitted to the FWS titled "Wetland Flora, Fauna, and Water Quality Assessment at Topock Marsh—July 2011–March 2012 (J.S. Daniels and J.C. Haegele, unpub. data, 2009). Instead, the coverage ratings are listed in table 8 and our observation points are mapped on figure 21. Because Topock Marsh is too large to measure all plant coverage directly, SAV and emergent vegetation coverage was estimated using the World View 2 land cover model created by our CSU colleagues, Nick Young and Ryan Anderson. Using the model's prediction, the total area covered by SAV in October 2014 was 1.536 square kilometers (km^2) (379.6 acres) within Topock Marsh (Young and others, 2015).

Emergent Aquatic Vegetation

The two dominant emergent plant species throughout Topock Marsh were cattail (*Typha* sp.) and California bulrush. Common reeds (*Phragmites australis*) were also present and growing in at least three locations along the marsh; from 2011 to 2014, the common reed patches became noticeably larger. Various additional plants were noted at one to a few locations within the marsh but at very low densities. Those plants included the invasive giant reed (*Arundo donax*), Olney bulrush (*Schoenoplectus americanus*), river bulrush (*Bolboschoenus fluviatilis*), spikerush (*Eleocharis* sp.), small-fruit bulrush (*Scirpus microcarpus*), Leopold rush (*Juncus acutus* ssp. *Leopoldii*), milkweed (*Asclepias* sp.), and pennywort (*Hydrocotyle* sp.).

During vegetation surveys in 2011, it was noted that many cattail stands along the western bank of the western channel were showing signs of stress as their roots and rhizomes were high above the water line, many cattail leaves were brown, and catkins were rare [see first photo on cover page]), and in many shallow areas (<0.6 m [<2.0 ft] deep) new California bulrush plants had spread from established stands into deeper water. During the growing season of 2012, however, both cattail and California bulrush had a "full blown recovery with no evidence of mortality" (Rob Randall, AZFWCO, written commun., 2012). Subsequently, throughout 2013 and 2014, no signs of dieback of cattail caused by the low water depths during 2011 were observed, and both cattail and California bulrush have thrived up through our final sampling day, October 7, 2014.

Emergent vegetation coverage was calculated by plant species using the CSU land cover model. Total areal coverage of all emergent species combined was 10.662 km^2 (2,634.6 acres) during October 2014 when the WorldView-2 images were taken (Young and others, 2015). Details of the methods and results of the land cover model are provided in the report by Young and others (2015).

Phytoplankton

The phytoplankton taxa found in this study are listed in table 10. Species richness during the entire 4-year study was 240 individual phytoplankton taxa (table 10). During the low water sampling period (August 2011–March 2012), 193 individual phytoplankton taxa were found, however, species richness in a given sample ranged from 15 to 52 depending on the location and month (table 10). During this time, phytoplankton density stayed relatively low, with the exception of a large number of blue-green algae (Cyanobacteria) cells that appeared in October 2011 at TP-8 (fig. 23*A*). However, even though individual numbers were low, phytoplankton biovolume at TP-6 reached as high as 4 million $\mu m^3/mL$ and 6 million $\mu m^3/mL$ in February and March 2012, respectively, with diatoms (Bacillariophyceae) making up 98 percent of the total cells (fig. 23*B*).

During the high-water sampling period (June 2013–October 2014), species richness of phytoplankton was nearly 50 percent lower than in 2011–12 (number of taxa = 100) (table 10), but cell densities and biovolume far exceeded those collected in 2011–12. Taxa responsible for the highest biovolumes varied between dinoflagellates (Pyrrophycophyta), blue-green algae, golden-brown algae (Chrysophyta), and diatoms at TP-3, TP-2, TP-6, and TP-8, respectively (fig. 23*B*). Taxa generating the highest cell density during that period was golden-brown algae at TP-3, and blue-green algae at TP-2, TP-3, and TP-8 (fig. 23*A*).

Overall, total phytoplankton density and biovolume were greatest during July 2013 at TP-8 (figs. 23*A* and *B*) immediately following the hottest air temperatures of the study period (fig. 3*A*). At that time, diatoms made up more than 43 percent of the total phytoplankton biovolume, blue-green algae made up more than 32 percent, and green algae (Chlorophyta) made up more than 18 percent (fig. 23*B*). Plankton were not sampled during the hottest months in 2014.

Zooplankton

The zooplankton taxa found in Topock Marsh at each sampling station and for each sampling date are listed in table 11. Species richness for zooplankton during the 4-year study period included 67 different taxa (table 11). Figures 24*A* and *B* illustrate the density and biomass of zooplankton by date and location. The highest density and biomass of zooplankton were observed in February 2014, and TP-6 had the highest cell density and biomass values that month. The second highest density and biomass occurred in April 2014. Rotifers (Rotifera) had the highest densities in February and April 2014 at all sampling locations, but cladocerans (Cladocera) made up the majority of the biomass.

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.

[TP, sampling station, O^1, October 2011; F^2, February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^3, October 2013; F^4, February 2014; A, April 2014; O^4, October 2014; A^1, August 2011]

TP-3

Taxonomy / Phylum / *Genus species*	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
BACILLARIOPHYTA (diatoms)									
Achnanthidium duthiei									
Achnanthidium minutissimum		X	X	X		X	X	X	X
Achnanthidium spp.	X								
Amphipleura pellucida			X						
Amphiprora spp.									
Amphora libyca									
Amphora ovalis									
Amphora sp.							X	X	X
Anomoeoneis sphaerophora									
Aulacoseira granulata					X			X	
Aulacoseira sp.									
Brachysira sp.			X						
Caloneis bacillum			X						
Caloneis cf. *pulchra*			X						
Caloneis limosa									
Caloneis schumanniana		X	X						
Caloneis silicula								X	
Caloneis westii									
Caloneis sp.			X						
Cocconeis placentula	X		X	X			X	X	X
Craticula ambigua									
Craticula buderi									
Craticula cuspidata									
Craticula molesta			X						
Cyclotella cf. *comensis*									
Cyclotella comensis									
Cyclotella gamma		X							
Cyclotella ocellata			X	X		X			X
Cyclotella sp.	X		X						
Cymatopleura elliptica			X						
Cymatopleura solea									
Cymbella affinis									
Cymbella delicatula									
Cymbella naviculiformis									

TP-2

Taxonomy / Phylum / *Genus species*	2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
BACILLARIOPHYTA (diatoms)										
Achnanthidium duthiei	X		X	X						
Achnanthidium minutissimum			X	X	X	X	X	X	X	
Achnanthidium spp.		X								
Amphipleura pellucida										
Amphiprora spp.										
Amphora libyca										
Amphora ovalis										
Amphora sp.							X			
Anomoeoneis sphaerophora										
Aulacoseira granulata										
Aulacoseira sp.										
Brachysira sp.										
Caloneis bacillum										
Caloneis cf. *pulchra*										
Caloneis limosa										
Caloneis schumanniana				X						
Caloneis silicula										
Caloneis westii										
Caloneis sp.										
Cocconeis placentula		X	X	X	X			X	X	X
Craticula ambigua			X							
Craticula buderi				X						
Craticula cuspidata								X		
Craticula molesta				X						
Cyclotella cf. *comensis*			X							
Cyclotella comensis										
Cyclotella gamma			X							
Cyclotella ocellata							X			X
Cyclotella sp.	X									
Cymatopleura elliptica										
Cymatopleura solea		X						X		
Cymbella affinis			X							
Cymbella delicatula										
Cymbella naviculiformis										X

TP-6

Taxonomy / Phylum / *Genus species*	2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4	2014 *
BACILLARIOPHYTA (diatoms)											
Achnanthidium duthiei											
Achnanthidium minutissimum			X		X	X	X	X	X	X	X
Achnanthidium spp.	X	X									
Amphipleura pellucida				X							
Amphiprora spp.											
Amphora libyca			X	X							
Amphora ovalis											
Amphora sp.						X					
Anomoeoneis sphaerophora			X	X							
Aulacoseira granulata	X										
Aulacoseira sp.		X									
Brachysira sp.											
Caloneis bacillum											
Caloneis cf. *pulchra*											
Caloneis limosa	X										
Caloneis schumanniana			X	X							
Caloneis silicula									X		
Caloneis westii			X	X							
Caloneis sp.				X							
Cocconeis placentula		X	X	X		X		X	X	X	X
Craticula ambigua				X							
Craticula buderi											
Craticula cuspidata											
Craticula molesta											
Cyclotella cf. *comensis*											
Cyclotella comensis			X								
Cyclotella gamma			X								
Cyclotella ocellata							X		X		
Cyclotella sp.											
Cymatopleura elliptica				X							
Cymatopleura solea	X	X						X			
Cymbella affinis											
Cymbella delicatula											
Cymbella naviculiformis											

TP-8

Taxonomy / Phylum / *Genus species*	2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
BACILLARIOPHYTA (diatoms)										
Achnanthidium duthiei										
Achnanthidium minutissimum			X	X	X		X	X	X	X
Achnanthidium spp.	X	X								
Amphipleura pellucida										
Amphiprora spp.		X								
Amphora libyca			X							
Amphora ovalis				X						
Amphora sp.									X	
Anomoeoneis sphaerophora										
Aulacoseira granulata							X	X		
Aulacoseira sp.										
Brachysira sp.			X							
Caloneis bacillum										
Caloneis cf. *pulchra*										
Caloneis limosa	X									
Caloneis schumanniana			X	X						
Caloneis silicula										
Caloneis westii										
Caloneis sp.			X							
Cocconeis placentula				X					X	
Craticula ambigua										
Craticula buderi										
Craticula cuspidata										
Craticula molesta										
Cyclotella cf. *comensis*										
Cyclotella comensis										
Cyclotella gamma			X	X						
Cyclotella ocellata								X	X	X
Cyclotella sp.	X	X								
Cymatopleura elliptica										
Cymatopleura solea										
Cymbella affinis										
Cymbella delicatula			X							
Cymbella naviculiformis										

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy	TP-3									TP-2										TP-6											TP-8									
Phylum	2011	2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014				2011		2012		2013			2014		
Genus species	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]	*	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Cymbella proxima								X							X			X																						
Cymbella sp.			X								X									X			X																	
Cymbopleura frequens													X																											
Denticula cf. *elegans*												X																												
Denticula sp.								X																				X	X	X										
Diadesmis contenta												X																												
Diatoma moniliformis												X		X		X		X																						
Diatoma tenuis													X																											
Diatoma vulgare or vulgaris										X	X									X	X						X													
Diploneis elliptica						X							X										X											X						
Diploneis oblongella			X																																					
Diploneis ovalis																																							X	
Diploneis parma					X		X										X		X								X													
Diploneis puella		X																																						
Diploneis sp.									X			X																												
Encyonema minutum							X	X	X		X		X			X	X	X		X						X	X	X											X	
Encyonema sp.	X										X			X							X																			
Encyonopsis microcephala												X										X	X																	
Entomoneis sp.			X										X									X	X										X	X						
Epithemia sp.																					X		X																	
Eunotia exigua																																		X						
Eunotia sp.												X								X																				
Fallacia pygmaea			X																																					
Fragilaria bidens																							X																	
Fragilaria capucina		X	X			X	X		X	X	X	X		X		X	X	X	X	X	X	X				X	X	X		X	X	X	X		X	X			X	X
Fragilaria capucina var. *gracilis*												X																												
Fragilaria construens																				X																				
Fragilaria crotonensis				X	X								X	X	X																									
Fragilaria sp.	X									X										X	X										X	X								
Frustulia sp.	X																																							
Gomphoneis olivacea												X																					X							
Gomphonema cf. *parvulum*																						X																		
Gomphonema gracile			X										X									X	X				X		X	X			X	X						
Gomphonema sp.											X									X	X	X									X									
Gomphonema truncatum																				X	X																			

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy	TP-3								
Phylum	2011	2012		2013			2014		
Genus species	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Gyrosigma sp.	X					X	X	X	X
Gyrosigma spencerii									
Hippodonta capitata			X						
Mastogloia smithii			X				X		X
Mastogloia sp.									
Navicula capitatoradiata		X							
Navicula cryptocephala			X						
Navicula cryptotenella			X				X		
Navicula gregaria			X				X		
Navicula lancolata						X			
Navicula radiosa									
Navicula recens									
Navicula sp.		X	X	X	X				
Navicula trivialis									
Navicula veneta				X			X		
Navicula viridis									
Neidium sp.									
Nitzschia acicularis	X	X	X	X	X	X	X	X	
Nitzschia agnita		X							
Nitzschia amphibia			X	X		X	X		
Nitzschia angustata			X						
Nitzschia bryophila			X						
Nitzschia capitellata		X							
Nitzschia cf. *commutatoides*		X							
Nitzschia constricta							X		X
Nitzschia cf. *flexoides*									
Nitzschia cf. *gracilis*									
Nitzschia cf. *parvula*									
Nitzschia denticula									
Nitzschia dissipata		X	X						
Nitzschia gracilis									
Nitzschia inconspicua			X	X	X	X	X	X	X
Nitzschia intermedia									
Nitzschia levidensis				X	X				
Nitzschia linearis			X						
Nitzschia microcephala									

Taxonomy	TP-2									
Phylum	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Gyrosigma sp.					X			X		
Gyrosigma spencerii										
Hippodonta capitata			X							
Mastogloia smithii			X	X			X			X
Mastogloia sp.										
Navicula capitatoradiata				X						
Navicula cryptocephala										
Navicula cryptotenella			X		X			X	X	
Navicula gregaria										
Navicula lancolata						X				
Navicula radiosa				X						
Navicula recens										
Navicula sp.	X	X	X		X	X				
Navicula trivialis										
Navicula veneta						X		X		
Navicula viridis										
Neidium sp.	X									
Nitzschia acicularis				X				X		
Nitzschia agnita										
Nitzschia amphibia			X				X		X	
Nitzschia angustata										
Nitzschia bryophila										
Nitzschia capitellata										
Nitzschia cf. *commutatoides*										
Nitzschia constricta									X	
Nitzschia cf. *flexoides*										
Nitzschia cf. *gracilis*			X							
Nitzschia cf. *parvula*										
Nitzschia denticula			X							
Nitzschia dissipata										
Nitzschia gracilis				X						
Nitzschia inconspicua					X	X	X	X		X
Nitzschia intermedia										
Nitzschia levidensis									X	
Nitzschia linearis										
Nitzschia microcephala			X							

Taxonomy	TP-6										
Phylum	2011		2012		2013			2014			
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]	*
Gyrosigma sp.	X							X	X	X	X
Gyrosigma spencerii				X							
Hippodonta capitata											
Mastogloia smithii			X	X		X	X	X			X
Mastogloia sp.											
Navicula capitatoradiata						X					
Navicula cryptocephala			X								
Navicula cryptotenella				X	X						X
Navicula gregaria			X	X				X	X		
Navicula lancolata											
Navicula radiosa											
Navicula recens											
Navicula sp.	X	X	X	X	X	X					
Navicula trivialis								X			
Navicula veneta								X			
Navicula viridis											
Neidium sp.	X										
Nitzschia acicularis			X				X				
Nitzschia agnita											
Nitzschia amphibia			X	X	X	X		X			
Nitzschia angustata			X								
Nitzschia bryophila											
Nitzschia capitellata											
Nitzschia cf. *commutatoides*											
Nitzschia constricta								X	X		
Nitzschia cf. *flexoides*				X							
Nitzschia cf. *gracilis*											
Nitzschia cf. *parvula*			X								
Nitzschia denticula				X							
Nitzschia dissipata											
Nitzschia gracilis											
Nitzschia inconspicua					X	X	X		X		
Nitzschia intermedia			X								
Nitzschia levidensis											
Nitzschia linearis			X								
Nitzschia microcephala											

Taxonomy	TP-8									
Phylum	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Gyrosigma sp.					X				X	X
Gyrosigma spencerii										
Hippodonta capitata			X							
Mastogloia smithii			X		X			X		X
Mastogloia sp.				X						
Navicula capitatoradiata										
Navicula cryptocephala										
Navicula cryptotenella					X				X	
Navicula gregaria										
Navicula lancolata								X		
Navicula radiosa										
Navicula recens			X							
Navicula sp.	X	X	X	X		X				
Navicula trivialis			X							
Navicula veneta										
Navicula viridis				X						
Neidium sp.	X									
Nitzschia acicularis			X	X	X	X	X			X
Nitzschia agnita										
Nitzschia amphibia			X					X	X	
Nitzschia angustata										
Nitzschia bryophila										
Nitzschia capitellata										
Nitzschia cf. *commutatoides*										
Nitzschia constricta								X		
Nitzschia cf. *flexoides*										
Nitzschia cf. *gracilis*										
Nitzschia cf. *parvula*										
Nitzschia denticula										
Nitzschia dissipata										
Nitzschia gracilis										
Nitzschia inconspicua					X	X	X	X	X	X
Nitzschia intermedia			X							
Nitzschia levidensis									X	
Nitzschia linearis										
Nitzschia microcephala										

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy	TP-3									TP-2										TP-6											TP-8									
Phylum	2011	2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014				2011		2012		2013			2014		
Genus species	O¹	F²	M	Jn	Jl	O³	F⁴	A	O⁴	A¹	O¹	F²	M	Jn	Jl	O³	F⁴	A	O⁴	A¹	O¹	F²	M	Jn	Jl	O³	F⁴	A	O⁴	*	A¹	O¹	F²	M	Jn	Jl	O³	F⁴	A	O⁴
Nitzschia palea	X	X	X	X		X	X	X	X			X	X	X		X	X					X	X	X	X			X					X	X	X		X	X	X	
Nitzschia perminuta				X		X		X	X			X		X		X								X		X		X	X	X					X		X			
Nitzschia pura			X																																					
Nitzschia reversa																						X																		
Nitzschia scalaris													X									X																		
Nitzschia sigma													X																											
Nitzschia sp.	X		X			X							X							X		X	X	X						X	X			X						
Nitzschia subacicularis			X									X										X																		
cf. *Pinnularia* sp.																							X																	
Pinnularia sp.																				X	X																			
Planothidium lanceolata																				X																				
Pleurosigma elongatum		X																																X						
Pleurosigma salinarum			X																			X	X										X							
Pleurosigma sp.													X																											
Pseudostaurosira brevistriata			X	X			X	X	X			X	X				X	X				X	X	X			X						X	X		X			X	
Pseudostaurosira brevistriata var. *trigibba*		X	X									X	X									X	X										X	X						
Puncticulata bodanica													X																											
Reimeria sinuata																		X																						
Rhoicosphenia abbreviata												X																												
Rhopalodia gibba					X	X	X		X		X		X						X	X		X	X	X	X		X		X	X	X									X
Sellaphora laevissima													X																											
Sellaphora pupula																																	X							
Sellaphora sp.																						X																		
Stauroneis sp.																				X											X									
Staurosira construens			X	X				X	X					X					X			X	X	X	X	X	X	X		X					X	X	X	X		X
Staurosira elliptica			X																																					
Staurosirella lapponica		X	X									X	X									X	X											X						
Staurosirella pinnata				X	X	X	X	X	X					X		X	X					X	X	X	X	X	X	X	X	X					X	X	X	X	X	X
Stephanocyclus meneghiniana			X	X	X			X	X				X	X	X	X	X	X				X	X			X	X		X	X					X	X	X	X	X	
Stephanodiscus niagarae				X																																	X			
Stephanodiscus parvus				X	X				X					X	X		X	X	X					X	X	X	X								X	X	X	X		X
Stephanodiscus sp.												X										X									X	X	X							
Surirella angusta																							X																	
Surirella brebissonii		X																					X																	
Surirella minuta													X																											

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O^{1}, October 2011; F^{2}, February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^{3}, October 2013; F^{4}, February 2014; A, April 2014; O^{4}, October 2014; A^{1}, August 2011]

Taxonomy	TP-3									TP-2										TP-6											TP-8									
Phylum	2011	2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014				2011		2012		2013			2014		
Genus species	O^{1}	F^{2}	M	Jn	Jl	O^{3}	F^{4}	A	O^{4}	A^{1}	O^{1}	F^{2}	M	Jn	Jl	O^{3}	F^{4}	A	O^{4}	A^{1}	O^{1}	F^{2}	M	Jn	Jl	O^{3}	F^{4}	A	O^{4}	*	A^{1}	O^{1}	F^{2}	M	Jn	Jl	O^{3}	F^{4}	A	O^{4}
Surirella ovata										X										X	X																			
Surirella sp.																				X	X	X																		
Synedra delicatissima		X	X									X	X							X		X	X										X							
Synedra spp.	X									X	X	X								X											X	X								
Synedra tenera			X		X	X	X	X	X			X		X	X	X	X		X			X		X	X		X	X					X	X	X	X	X	X	X	X
Synedra ulna			X	X		X	X	X				X		X	X	X		X	X				X	X	X		X	X	X	X			X		X	X			X	X
Tryblionella apiculata				X																				X																
Tryblionella constricta			X																				X										X							
Tryblionella levidensis																						X																		
CHLOROPHYTA (green algae)																																								
Botryococcus braunii					X		X										X										X											X		
Bulbochaete sp.																				X																				
Characium ambiguum				X				X						X				X										X		X						X			X	
cf. *Chlamydomonas* sp.																																	X							
Chlamydomonas sp.				X	X		X			X				X											X	X					X	X			X	X				
Chlorella sp.												X																												
Coelastrum microporum						X			X									X						X	X	X		X		X									X	X
Cosmarium sp.				X		X		X									X	X						X				X	X	X					X	X			X	
Crucigenia quadrata								X				X		X	X	X			X					X	X	X		X							X					
Crucigenia tetrapedia		X	X									X										X																		
Dictyosphaerium pulchellum																																X								
Eudorina elegans																																X								
Kirchneriella contorta				X	X			X						X											X	X						X								
Lagerheimia genevensis												X																												
Lobomonas sp.												X																												
Monoraphidium minutum																																	X							
Oedogonium sp.	X										X										X									X									X	
Oocystis parva								X																									X						X	
Oocystis sp.																		X									X											X		
Pediastrum duplex																				X								X		X										
Pyramimonas tetrarhynchus				X	X	X	X	X	X					X	X		X	X	X					X	X	X	X	X	X	X					X	X	X	X	X	X
Raphidocelis contorta													X																											
Scenedesmus acuminatus																															X	X								
Scenedesmus bijuga				X	X			X						X	X									X	X	X				X					X	X			X	X
Scenedesmus brasiliensis																															X									

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

TP-3

Taxonomy / Phylum / *Genus species*	2011	2012		2013			2014		
	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Scenedesmus communis				X					
Scenedesmus dimorphus						X			
Scenedesmus intermedius									
Scenedesmus opoliensis var. *mononensis*			X						
Scenedesmus quadricauda								X	X
Scenedesmus sp.									
Scenedesmus subspicatus			X						
Selenastrum gracile									
Selenastrum minutum									
Sphaerocystis schroeteri								X	
Sphaerocystis sp.									
Staurastrum spp.				X					X
Tetraedron caudatum								X	
Tetraedron gracile					X				
Tetraedron limneticum									
Tetraedron minimum				X				X	
CHRYSOPHYTA (golden algae)									
Dinobryon sp.	X								
Mallomonas pseudocoronata				X				X	
Mallomonas sp.		X							
Pseudokephyrion pseudo-spirale		X	X						
Pseudokephyrion sp.		X							
Synura sp.									
CRYPTOPHYTA (cryptomonads)									
Cryptomonas sp.					X				
Rhodomonas minuta var. *nannoplanctica*									
Rhodomonas spp.			X	X	X	X	X	X	X

TP-2

Taxonomy / Phylum / *Genus species*	2011		2012		2013			2014		
	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Scenedesmus communis					X					
Scenedesmus dimorphus					X					X
Scenedesmus intermedius			X							
Scenedesmus opoliensis var. *mononensis*										
Scenedesmus quadricauda						X	X	X	X	X
Scenedesmus sp.				X						
Scenedesmus subspicatus										
Selenastrum gracile										
Selenastrum minutum										
Sphaerocystis schroeteri					X	X				X
Sphaerocystis sp.										
Staurastrum spp.						X				X
Tetraedron caudatum									X	
Tetraedron gracile										
Tetraedron limneticum		X								
Tetraedron minimum			X			X	X		X	X
CHRYSOPHYTA (golden algae)										
Dinobryon sp.									X	
Mallomonas pseudocoronata					X				X	
Mallomonas sp.							X		X	
Pseudokephyrion pseudo-spirale										
Pseudokephyrion sp.				X						
Synura sp.										
CRYPTOPHYTA (cryptomonads)										
Cryptomonas sp.	X			X	X	X				X
Rhodomonas minuta var. *nannoplanctica*										
Rhodomonas spp.			X	X	X	X	X	X	X	X

TP-6

Taxonomy / Phylum / *Genus species*	2011		2012		2013			2014			
	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]	*
Scenedesmus communis					X						
Scenedesmus dimorphus						X			X		
Scenedesmus intermedius											
Scenedesmus opoliensis var. *mononensis*											
Scenedesmus quadricauda		X				X	X	X	X	X	X
Scenedesmus sp.		X									
Scenedesmus subspicatus											
Selenastrum gracile						X					X
Selenastrum minutum											
Sphaerocystis schroeteri						X					X
Sphaerocystis sp.											
Staurastrum spp.						X					X
Tetraedron caudatum						X					X
Tetraedron gracile											
Tetraedron limneticum											
Tetraedron minimum					X	X	X		X		X
CHRYSOPHYTA (golden algae)											
Dinobryon sp.									X		
Mallomonas pseudocoronata											
Mallomonas sp.									X		
Pseudokephyrion pseudo-spirale				X							
Pseudokephyrion sp.											
Synura sp.											
CRYPTOPHYTA (cryptomonads)											
Cryptomonas sp.		X			X	X				X	X
Rhodomonas minuta var. *nannoplanctica*		X									
Rhodomonas spp.			X		X	X	X	X	X	X	X

TP-8

Taxonomy / Phylum / *Genus species*	2011		2012		2013			2014		
	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Scenedesmus communis					X					
Scenedesmus dimorphus					X	X				X
Scenedesmus intermedius										
Scenedesmus opoliensis var. *mononensis*			X							
Scenedesmus quadricauda	X	X				X	X	X	X	X
Scenedesmus sp.	X	X		X						
Scenedesmus subspicatus			X							
Selenastrum gracile										
Selenastrum minutum		X								
Sphaerocystis schroeteri					X	X		X	X	X
Sphaerocystis sp.				X						
Staurastrum spp.		X				X				
Tetraedron caudatum			X		X	X				
Tetraedron gracile						X				
Tetraedron limneticum										
Tetraedron minimum										
CHRYSOPHYTA (golden algae)										
Dinobryon sp.									X	
Mallomonas pseudocoronata									X	
Mallomonas sp.									X	X
Pseudokephyrion pseudo-spirale										
Pseudokephyrion sp.				X						
Synura sp.		X								
CRYPTOPHYTA (cryptomonads)										
Cryptomonas sp.	X	X		X		X				X
Rhodomonas minuta var. *nannoplanctica*	X	X								
Rhodomonas spp.			X		X	X	X	X	X	X

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy / Phylum / *Genus species*	TP-3 2011 O[1]	TP-3 2012 F[2]	TP-3 2012 M	TP-3 2013 Jn	TP-3 2013 Jl	TP-3 2013 O[3]	TP-3 2014 F[4]	TP-3 2014 A	TP-3 2014 O[4]
CYANOPHYTA (blue-green algae)									
Anabaena oscillarioides									
Anabaena spp.									
Anabaenopsis circularis									
Anabaenopsis sp.									
Aphanizomenon flos-aquae							X		
Calothrix stagnalis									
Chroococcus dispersus									
Chroococcus minimus				X					
Chroococcus minutus									
Chroococcus planctonicus				X					
Chroococcus sp.									
Cylindrospermopsis raciborskii									
Leptolyngbya sp.									
Lyngbya sp.		X							
Merismopedia punctata								X	
Microcystis aeruginosa				X		X			
Oscillatoria spp.									
Oscillatoria tenuis									
Planktolyngbya circumcreta								X	
Planktolyngbya contorta				X					
Planktolyngbya limnetica									
cf. *Planktolyngbya* sp.									
Planktolyngbya sp.									
Pseudanabaena galeata									
Pseudanabaena limnetica									
Pseudanabaena spp.									
Raphidiopsis curvata									
Rhabdoderma lineare									
Tolypothrix spp.									

Taxonomy / Phylum / *Genus species*	TP-2 2011 A[1]	TP-2 2011 O[1]	TP-2 2012 F[2]	TP-2 2012 M	TP-2 2013 Jn	TP-2 2013 Jl	TP-2 2013 O[3]	TP-2 2014 F[4]	TP-2 2014 A	TP-2 2014 O[4]
CYANOPHYTA (blue-green algae)										
Anabaena oscillarioides										
Anabaena spp.										
Anabaenopsis circularis										
Anabaenopsis sp.										
Aphanizomenon flos-aquae										
Calothrix stagnalis										
Chroococcus dispersus						X			X	X
Chroococcus minimus							X			
Chroococcus minutus										
Chroococcus planctonicus										
Chroococcus sp.										
Cylindrospermopsis raciborskii										
Leptolyngbya sp.		X								
Lyngbya sp.										
Merismopedia punctata										X
Microcystis aeruginosa						X				X
Oscillatoria spp.										
Oscillatoria tenuis		X								
Planktolyngbya circumcreta							X			X
Planktolyngbya contorta										
Planktolyngbya limnetica										X
cf. *Planktolyngbya* sp.			X							
Planktolyngbya sp.										
Pseudanabaena galeata										
Pseudanabaena limnetica										
Pseudanabaena spp.										
Raphidiopsis curvata					X					
Rhabdoderma lineare										
Tolypothrix spp.										

Taxonomy / Phylum / *Genus species*	TP-6 2011 A[1]	TP-6 2011 O[1]	TP-6 2012 F[2]	TP-6 2012 M	TP-6 2013 Jn	TP-6 2013 Jl	TP-6 2013 O[3]	TP-6 2014 F[4]	TP-6 2014 A	TP-6 2014 O[4]	TP-6 2014 *
CYANOPHYTA (blue-green algae)											
Anabaena oscillarioides	X										
Anabaena spp.	X										
Anabaenopsis circularis											
Anabaenopsis sp.											
Aphanizomenon flos-aquae											X
Calothrix stagnalis	X										
Chroococcus dispersus						X	X			X	X
Chroococcus minimus					X	X					
Chroococcus minutus											
Chroococcus planctonicus											
Chroococcus sp.											
Cylindrospermopsis raciborskii											
Leptolyngbya sp.											
Lyngbya sp.											
Merismopedia punctata						X	X				X
Microcystis aeruginosa						X	X				X
Oscillatoria spp.		X									
Oscillatoria tenuis		X									
Planktolyngbya circumcreta					X	X					
Planktolyngbya contorta					X	X					
Planktolyngbya limnetica					X	X	X			X	X
cf. *Planktolyngbya* sp.											
Planktolyngbya sp.											
Pseudanabaena galeata		X									
Pseudanabaena limnetica											
Pseudanabaena spp.		X									
Raphidiopsis curvata						X					
Rhabdoderma lineare											
Tolypothrix spp.	X										

Taxonomy / Phylum / *Genus species*	TP-8 2011 A[1]	TP-8 2011 O[1]	TP-8 2012 F[2]	TP-8 2012 M	TP-8 2013 Jn	TP-8 2013 Jl	TP-8 2013 O[3]	TP-8 2014 F[4]	TP-8 2014 A	TP-8 2014 O[4]
CYANOPHYTA (blue-green algae)										
Anabaena oscillarioides	X									
Anabaena spp.	X	X								
Anabaenopsis circularis					X	X				
Anabaenopsis sp.		X								
Aphanizomenon flos-aquae										
Calothrix stagnalis										
Chroococcus dispersus					X	X				X
Chroococcus minimus					X	X				
Chroococcus minutus		X								
Chroococcus planctonicus										
Chroococcus sp.		X	X							
Cylindrospermopsis raciborskii						X				
Leptolyngbya sp.										
Lyngbya sp.										
Merismopedia punctata					X	X				
Microcystis aeruginosa		X			X	X				X
Oscillatoria spp.										
Oscillatoria tenuis										
Planktolyngbya circumcreta						X				X
Planktolyngbya contorta					X	X				
Planktolyngbya limnetica					X	X				X
cf. *Planktolyngbya* sp.										
Planktolyngbya sp.			X							
Pseudanabaena galeata										
Pseudanabaena limnetica										X
Pseudanabaena spp.	X									
Raphidiopsis curvata						X				
Rhabdoderma lineare						X				
Tolypothrix spp.										

Table 10. Phytoplankton taxa collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station, O^1, October 2011; F^2, February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^3, October 2013; F^4, February 2014; A, April 2014; O^4, October 2014; A^1, August 2011]

Taxonomy / Phylum / *Genus species*	TP-3 2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
EUGLENOPHYTA (euglenoids)									
Euglena acus									
Euglena sp.	X			X	X			X	X
Lepocinclis spyrogyroides		X							
Phacus sp.				X	X			X	X
Trachelomonas spp.		X	X						
PYRROPHYTA (dinoflagellates)									
Ceratium hirundinella									
Glenodinium palustre				X					X
Glenodinium quadridens				X	X				
Glenodinium sp.									
Gymnodinium palustre									
Peridinium inconspicuum									
Peridinium sp.	X								
Total number of taxa by date and location	**15**	**25**	**52**	**39**	**23**	**22**	**26**	**36**	**28**

Taxonomy / Phylum / *Genus species*	TP-2 2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
EUGLENOPHYTA (euglenoids)										
Euglena acus	X	X								
Euglena sp.	X	X			X	X				X
Lepocinclis spyrogyroides										
Phacus sp.		X			X	X				
Trachelomonas spp.			X							
PYRROPHYTA (dinoflagellates)										
Ceratium hirundinella										
Glenodinium palustre					X					
Glenodinium quadridens					X					
Glenodinium sp.	X									X
Gymnodinium palustre										
Peridinium inconspicuum	X									
Peridinium sp.	X	X								
Total number of taxa by date and location	**16**	**20**	**46**	**37**	**35**	**25**	**22**	**23**	**28**	**28**

Taxonomy / Phylum / *Genus species*	TP-6 2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4 *	2014 O^4 *
EUGLENOPHYTA (euglenoids)											
Euglena acus											
Euglena sp.						X			X		
Lepocinclis spyrogyroides			X								
Phacus sp.					X				X		
Trachelomonas spp.	X		X								
PYRROPHYTA (dinoflagellates)											
Ceratium hirundinella											
Glenodinium palustre											
Glenodinium quadridens					X						
Glenodinium sp.											
Gymnodinium palustre					X						
Peridinium inconspicuum											
Peridinium sp.											
Total number of taxa by date and location	**32**	**24**	**47**	**41**	**32**	**39**	**25**	**28**	**31**	**17**	**36**

Taxonomy / Phylum / *Genus species*	TP-8 2011 A^1	2011 O^1	2012 F^2	2012 M	2013 Jn	2013 Jl	2013 O^3	2014 F^4	2014 A	2014 O^4
EUGLENOPHYTA (euglenoids)										
Euglena acus										
Euglena sp.		X			X	X	X		X	X
Lepocinclis spyrogyroides										
Phacus sp.	X			X	X	X			X	
Trachelomonas spp.			X				X			
PYRROPHYTA (dinoflagellates)										
Ceratium hirundinella									X	
Glenodinium palustre					X					
Glenodinium quadridens						X				
Glenodinium sp.										X
Gymnodinium palustre										
Peridinium inconspicuum										
Peridinium sp.		X								
Total number of taxa by date and location	**24**	**27**	**39**	**25**	**35**	**38**	**17**	**20**	**34**	**29**

*Two separate samples, replication 1 and 2, were collected from this location on this date.

Species richness 2011–2012: 193

Species richness 2013–2014: 100

Species richness: Total number of taxa occurring in Topock during 2011–2014 = 240

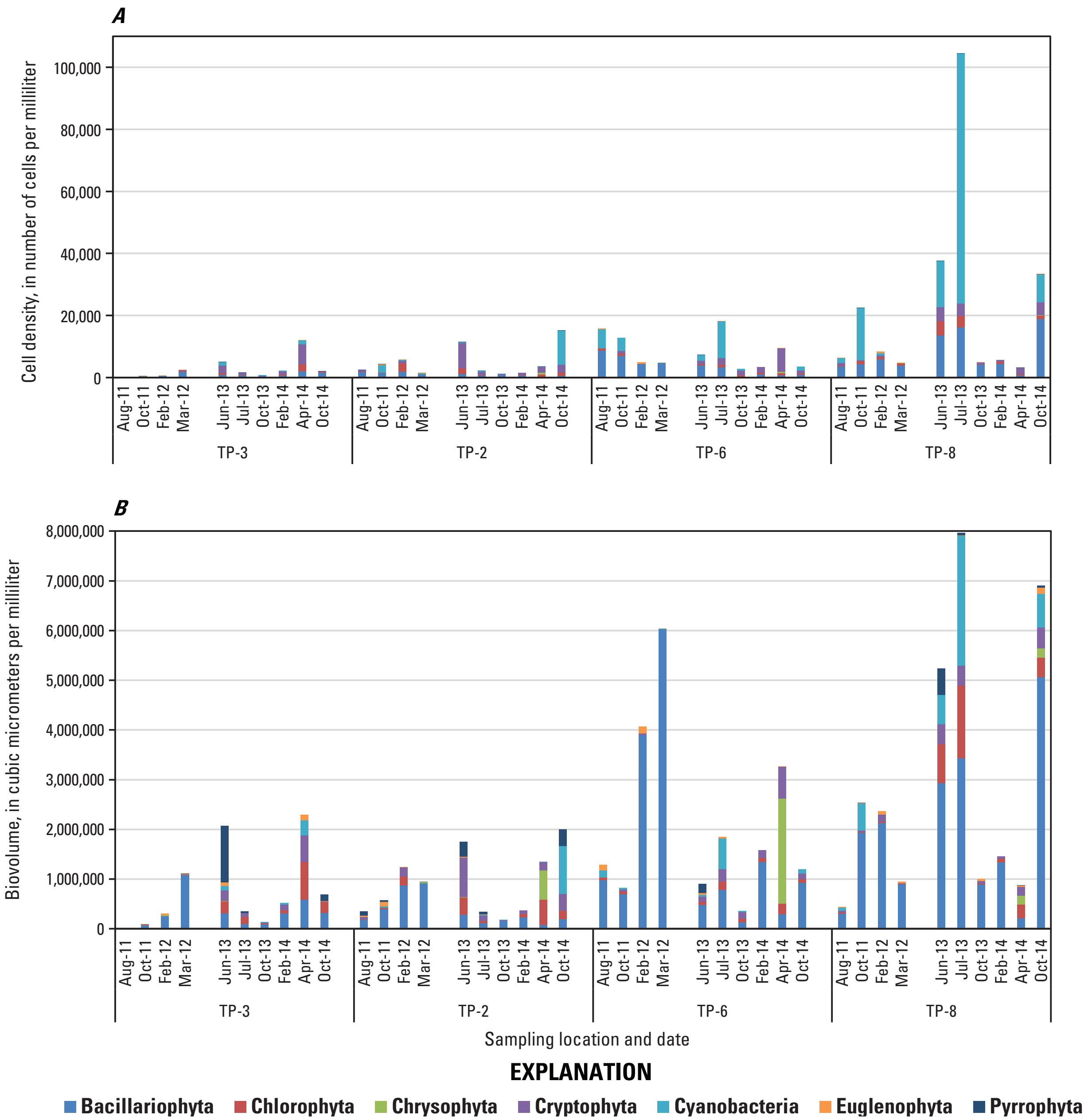

Figure 23. Density and biovolume of phytoplankton data from sampling stations in Topock Marsh, Arizona, from August 2011 to October 2014. *A*, total density and *B*, biovolume of phytoplankton. Note stations are shown in upstream to downstream order. (TP, sampling station)

Table 11. Zooplankton taxa collected in Topock Marsh at each sampling station on each sampling date.

[TP, sampling station; O^1, October 2011; F^2, February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^3, October 2013; F^4, February 2014; A, April 2014; O^4, October 2014; A^1, August 2011]

Taxonomy	TP-3								
Phylum, Class, or Order	2011	2012		2013			2014		
Genus species	O^1	F^2	M	Jn	Jl	O^3	F^4	A	O^4
CLADOCERA									
Alona affinis									
Alona guttata									
Bosmina longirostris			X				X	X	
Ceriodaphnia spp.							X		
Chydorus spp.									
Chydorus sphaericus									
Daphnia ambigua			X						
Daphnia lumholtzi [b]		X							
Daphnia parvula							X		
Daphnia spp.							X		
Diaphanosoma brachyurum									
Eubosmina longispina			X						
Latona parviremis									
Sida crystallina									
Simocephalus serrulatus									
Simocephalus spp.									
COPEPODA									
Acanthocyclops robustus			X						
Acanthocyclops vernalis (cyclopoid)		X							
Leptodiaptomus siciloides									
Mesocyclops edax									
Tropocyclops prasinus (cyclopoid)									
calanoid						X		X	
cyclopoid					X	X	X	X	X
nauplii				X	X	X	X	X	X
ROTIFERA									
Anuraeopsis fissa					X				
Ascomorpha ovalis									
Asplanchna priodonta		X	X						
bdelloid									
Brachionus angularis	X	X		X	X	X			X

Taxonomy	TP-2									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A^1	O^1	F^2	M	Jn	Jl	O^3	F^4	A	O^4
CLADOCERA										
Alona affinis		X								
Alona guttata										
Bosmina longirostris			X	X	X		X	X	X	
Ceriodaphnia spp.				X						
Chydorus spp.										
Chydorus sphaericus										
Daphnia ambigua				X						
Daphnia lumholtzi [b]				X						
Daphnia parvula										
Daphnia spp.								X		
Diaphanosoma brachyurum	X						X			
Eubosmina longispina				X						
Latona parviremis										
Sida crystallina										
Simocephalus serrulatus										
Simocephalus spp.										
COPEPODA										
Acanthocyclops robustus										
Acanthocyclops vernalis (cyclopoid)										
Leptodiaptomus siciloides				X						
Mesocyclops edax			X							
Tropocyclops prasinus (cyclopoid)										
calanoid					X		X		X	
cyclopoid							X	X	X	X
nauplii					X	X	X	X	X	X
ROTIFERA										
Anuraeopsis fissa	X					X				
Ascomorpha ovalis										
Asplanchna priodonta				X						
bdelloid										
Brachionus angularis	X	X			X	X			X	X

Taxonomy	TP-6										
Phylum, Class, or Order	2011		2012		2013			2014			
Genus species	A^1	O^1	F^2	M	Jn	Jl	O^3	F^4	A	O^4 [a]	
CLADOCERA											
Alona affinis											
Alona guttata											
Bosmina longirostris		X	X	X	X		X	X	X	X	
Ceriodaphnia spp.	X									X	X
Chydorus spp.			X							X	X
Chydorus sphaericus		X									
Daphnia ambigua				X							
Daphnia lumholtzi [b]				X				X			
Daphnia parvula								X			
Daphnia spp.								X			
Diaphanosoma brachyurum		X								X	
Eubosmina longispina				X							
Latona parviremis		X									
Sida crystallina										X	X
Simocephalus serrulatus		X									
Simocephalus spp.										X	
COPEPODA											
Acanthocyclops robustus				X							
Acanthocyclops vernalis (cyclopoid)								X			
Leptodiaptomus siciloides											
Mesocyclops edax											
Tropocyclops prasinus (cyclopoid)		X				X				X	X
calanoid							X				X
cyclopoid						X	X	X		X	X
nauplii					X	X	X	X	X	X	X
ROTIFERA											
Anuraeopsis fissa	X					X				X	
Ascomorpha ovalis								X			
Asplanchna priodonta			X								
bdelloid											
Brachionus angularis	X	X		X	X	X	X		X		

Taxonomy	TP-8									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A^1	O^1	F^2	M	Jn	Jl	O^3	F^4	A	O^4
CLADOCERA										
Alona affinis										
Alona guttata				X						
Bosmina longirostris			X	X				X	X	
Ceriodaphnia spp.									X	
Chydorus spp.			X							
Chydorus sphaericus				X						
Daphnia ambigua									X	
Daphnia lumholtzi [b]			X				X	X		
Daphnia parvula								X		
Daphnia spp.								X		
Diaphanosoma brachyurum										
Eubosmina longispina										
Latona parviremis										
Sida crystallina										
Simocephalus serrulatus										
Simocephalus spp.										
COPEPODA										
Acanthocyclops robustus										
Acanthocyclops vernalis (cyclopoid)								X		
Leptodiaptomus siciloides										
Mesocyclops edax			X							
Tropocyclops prasinus (cyclopoid)										
calanoid							X	X	X	
cyclopoid							X	X	X	
nauplii					X	X	X	X	X	X
ROTIFERA										
Anuraeopsis fissa	X	X				X	X			X
Ascomorpha ovalis						X				
Asplanchna priodonta								X		X
bdelloid						X				
Brachionus angularis	X	X			X	X	X		X	X

Table 11. Zooplankton taxa collected in Topock Marsh at each sampling station on each sampling date.—Continued

[TP, sampling station; O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy	TP-3								
Phylum, Class, or Order	2011	2012		2013			2014		
Genus species	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Brachionus caudatus					X				
Brachionus patulus		X							
Brachionus quadridentatus f. *brevispinus*									
Brachionus variabilis		X	X				X		
Cephalodella spp.									
Collotheca spp.								X	
Conochiloides dossuarius									
Conochilus spp.			X						
Conochilus unicornis							X		
Euchlanis spp.									
Filinia longiseta	X			X	X		X	X	
Gastropus stylifer								X	
Hexarthra mira				X					X
Keratella americana	X					X			
Keratella cochlearis				X			X	X	X
Keratella cochlearis f. *tecta*									
Keratella quadrata		X	X				X	X	
Keratella testudo									
Keratella tropica		X	X				X		
Lecane spp.									
Lecane crepida									
Lepadella ovalis									
Liliferotrocha spp.									
Monostyla bulla									
Monostyla lunaris									
Notholca acuminata									
c.f. *Paradicranophorus* spp.									
Plationus patulus				X	X				X
Polyarthra dolichoptera		X	X						
Polyarthra remata				X	X	X			
Polyarthra vulgaris	X	X	X	X	X	X		X	X
Synchaeta spp.						X		X	
Testudinella patina									
Trichocerca multicrinis					X				
Trichocerca pusilla									

Taxonomy	TP-2									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Brachionus caudatus						X				
Brachionus patulus	X									
Brachionus quadridentatus f. *brevispinus*										
Brachionus variabilis				X				X		
Cephalodella spp.						X				
Collotheca spp.									X	
Conochiloides dossuarius									X	
Conochilus spp.				X						
Conochilus unicornis								X	X	
Euchlanis spp.							X			
Filinia longiseta	X	X			X	X	X	X	X	X
Gastropus stylifer										
Hexarthra mira					X					X
Keratella americana							X			
Keratella cochlearis					X			X	X	X
Keratella cochlearis f. *tecta*										
Keratella quadrata			X	X		X		X	X	
Keratella testudo		X								
Keratella tropica			X	X				X		
Lecane spp.				X				X		
Lecane crepida										
Lepadella ovalis					X					
Liliferotrocha spp.						X				X
Monostyla bulla										X
Monostyla lunaris				X		X				
Notholca acuminata				X						
c.f. *Paradicranophorus* spp.				X						
Plationus patulus					X	X				X
Polyarthra dolichoptera			X							
Polyarthra remata				X	X	X	X			
Polyarthra vulgaris	X	X	X	X	X	X	X	X	X	X
Synchaeta spp.					X		X		X	X
Testudinella patina					X					
Trichocerca multicrinis										
Trichocerca pusilla										

Taxonomy	TP-6										
Phylum, Class, or Order	2011		2012		2013			2014			
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4] [a]	
Brachionus caudatus					X	X	X		X		
Brachionus patulus	X	X									
Brachionus quadridentatus f. *brevispinus*											
Brachionus variabilis				X				X			
Cephalodella spp.											
Collotheca spp.											
Conochiloides dossuarius											
Conochilus spp.											
Conochilus unicornis				X				X	X		
Euchlanis spp.											
Filinia longiseta	X	X			X	X	X				
Gastropus stylifer									X		
Hexarthra mira	X				X	X				X	X
Keratella americana							X		X		
Keratella cochlearis					X	X		X	X	X	X
Keratella cochlearis f. *tecta*											
Keratella quadrata			X	X	X			X	X	X	
Keratella testudo											
Keratella tropica			X	X	X			X			
Lecane spp.											
Lecane crepida											X
Lepadella ovalis											
Liliferotrocha spp.											
Monostyla bulla		X	X								X
Monostyla lunaris											
Notholca acuminata											
c.f. *Paradicranophorus* spp.				X							
Plationus patulus					X	X				X	
Polyarthra dolichoptera			X	X							
Polyarthra remata					X		X		X		
Polyarthra vulgaris	X	X	X	X	X	X	X	X	X	X	X
Synchaeta spp.					X		X				
Testudinella patina											
Trichocerca multicrinis											
Trichocerca pusilla											

Taxonomy	TP-8									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Brachionus caudatus					X	X			X	
Brachionus patulus										
Brachionus quadridentatus f. *brevispinus*										X
Brachionus variabilis			X	X				X		
Cephalodella spp.										
Collotheca spp.										
Conochiloides dossuarius						X				
Conochilus spp.										X
Conochilus unicornis				X				X		
Euchlanis spp.										
Filinia longiseta	X	X			X	X				
Gastropus stylifer										
Hexarthra mira						X				
Keratella americana							X			
Keratella cochlearis					X	X			X	X
Keratella cochlearis f. *tecta*										
Keratella quadrata			X	X				X	X	
Keratella testudo										
Keratella tropica			X	X				X		
Lecane spp.										
Lecane crepida										
Lepadella ovalis										
Liliferotrocha spp.						X				X
Monostyla bulla										
Monostyla lunaris										
Notholca acuminata										
c.f. *Paradicranophorus* spp.										
Plationus patulus										
Polyarthra dolichoptera										
Polyarthra remata						X	X		X	
Polyarthra vulgaris	X	X	X	X	X	X	X	X		X
Synchaeta spp.						X	X		X	
Testudinella patina										
Trichocerca multicrinis										
Trichocerca pusilla	X	X				X				

Table 11. Zooplankton taxa collected in Topock Marsh at each sampling station on each sampling date.—Continued

[TP, sampling station; O[1], October 2011; F[2], February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F[4], February 2014; A, April 2014; O[4], October 2014; A[1], August 2011]

Taxonomy	TP-3								
Phylum, Class, or Order	2011	2012		2013			2014		
Genus species	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Trichocerca rousseleti									X
Trichocerca spp.					X				
Wolga spinifera									
Unidentified rotifer						X			
BIVALVIA									
Dreissena bugensis veliger [bc]			2						1
OSTRACODA									
Ostracod						X			
Total number of taxa by date and location	**4**	**10**	**12**	**8**	**11**	**10**	**12**	**11**	**9**

Taxonomy	TP-2									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Trichocerca rousseleti										X
Trichocerca spp.						X				
Wolga spinifera						X				
Unidentified rotifer					X			X		
BIVALVIA										
Dreissena bugensis veliger [bc]	9	1			4	15	1			
OSTRACODA										
Ostracod							X			
Total number of taxa by date and location	**7**	**6**	**6**	**17**	**15**	**15**	**13**	**13**	**13**	**12**

Taxonomy	TP-6										
Phylum, Class, or Order	2011		2012		2013			2014			
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4] [a]	
Trichocerca rousseleti											
Trichocerca spp.		X				X					
Wolga spinifera											
Unidentified rotifer											
BIVALVIA											
Dreissena bugensis veliger [bc]	4	1									
OSTRACODA											
Ostracod		X		X							X
Total number of taxa by date and location	**8**	**14**	**8**	**14**	**13**	**12**	**11**	**14**	**11**	**15**	**13**

Taxonomy	TP-8									
Phylum, Class, or Order	2011		2012		2013			2014		
Genus species	A[1]	O[1]	F[2]	M	Jn	Jl	O[3]	F[4]	A	O[4]
Trichocerca rousseleti										X
Trichocerca spp.										
Wolga spinifera										
Unidentified rotifer										
BIVALVIA										
Dreissena bugensis veliger [bc]										
OSTRACODA										
Ostracod										
Total number of taxa by date and location	**5**	**5**	**8**	**8**	**6**	**15**	**10**	**14**	**12**	**10**

[a]Two separate samples, replication 1 and 2, were collected from this location on this date.

[b]Nonnative species.

[c]Values provided are the number of individual veligers collected in footnote c in plankton tows where this taxon was present

Species richness 2011–2012: 45

Species richness 2013–2014: 52

Species richness: Total number of taxa occurring in Topock during 2011–2014 = 67

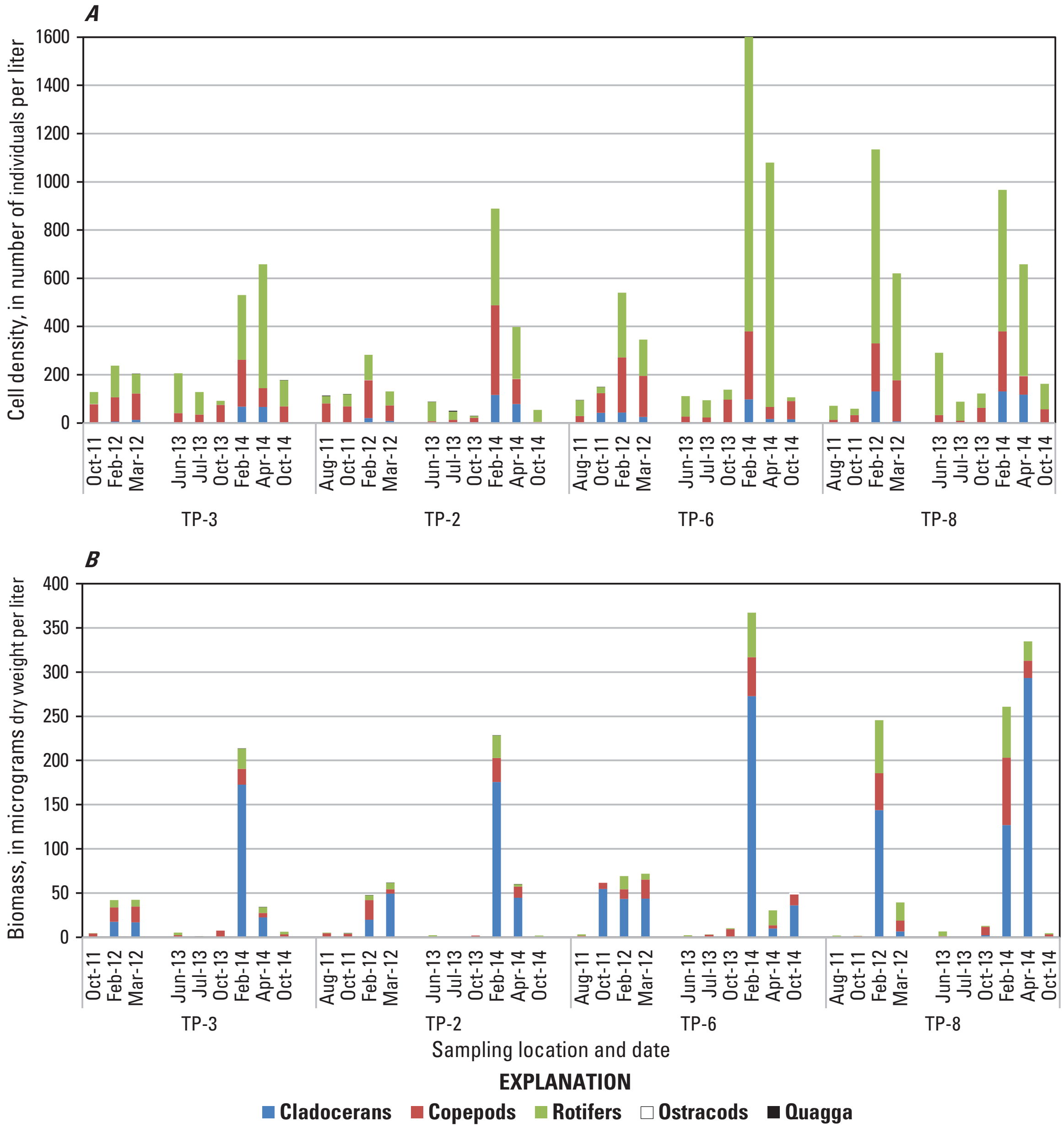

Figure 24. Density and biomass of zooplankton data from sampling stations in Topock, Arizona, from October 2011 to October 2014. *A*, total density and *B*, biomass of zooplankton. Note stations are shown in upstream to downstream order. (TP, sampling station)

Small Biota Sampling

Species richness of the aquatic macroinvertebrate taxa collected in Topock Marsh was 41 during 2011–12 and 72 during 2013–14 (table 12). There are no macroinvertebrate data for July 2011 because the shipping service lost all samples. During the entire 4-year study period, gastropods (specifically *Physa* sp.) and chironomids (several in the Chironomidae family) were abundant in all seasons. However, other taxa were also numerous at various times and places. For example, there were relatively high numbers of mayflies (*Caenis* sp.) in March 2012 at TP-2 and in June 2013 at TP-2 and TP-3; grass shrimp (*Palaemonetes* sp.) in October 2013 at TP-8; water boatman (Corixidae) larvae in February 2012 at TP-8, in March 2012 at TP-2, and in April 2014 at TP-8; and aquatic oligochaete worms (Oligochaeta) in June 2013 at TP-2, in February 2014 at TP-8, in April 2014 at TP-2, and in October 2014 at TP-2 and TP-8 (table 12). The fewest number of macroinvertebrates (201 individuals) were collected in July 2013, and the largest number (1,871 individuals) were collected in October 2013. Generally, each October tended to have the highest number of individual organisms (range = 611 to 1,871), but the highest number of taxa were collected in June 2013 (42 taxa) and April 2014 (41 taxa). Species richness ranged from 18 to 34 taxa per visit for the other 8 sampling trips. Large variations occurred between the sampling stations as well. Throughout the 10 sampling trips, TP-8 had the highest total number of individual organisms (mean = 321 individual macroinvertebrates) compared to the other sampling stations (mean number of individual invertebrates were 68, 178, and 109 for TP3, TP-2, and TP-6, respectively).

Adult quagga mussels (*Dreissena bugensis*) were first discovered in Topock Marsh in a sweep net sample from March 2012 at sampling station TP-2, where the Fire Break Canal flows into the marsh from the Colorado River. From sweep net samples, 12 quagga mussel adults (at least 1 from each sampling station) were collected in 2013, and 9 adults were collected in February 2014 (3 at station TP-3 and 6 at TP-2). No adults were collected in April 2014 or October 2014. Quagga mussel veligers (larval stage) were collected in zooplankton samples from TP-2 and TP-6 in August and September 2011, and from TP-3 in March 2012 (table 11). Several veligers were collected at TP-2 in June, July, and October 2013, and one individual was collected from TP-3 in October 2014 (table 11).

Fish Sampling

Gill net surveys were conducted by AGFD in the marsh each February from 2010 to 2015. These fish data, which were provided by Gregg Cummins of the AGFD, Region III Office in Kingman, Arizona, are presented in appendix 2 and are summarized in table 13. Locations where the 10 gill nets were set each year are illustrated in figures 25*A* and 25*B* and the number of fish captured each year within the entire marsh is provided in figure 26. The gill net data in table 13 are assembled into five regions: the north end, Fire Break Canal, Beal Lake outlet, Catfish Paradise, and South Dike.

The total number of fish caught in gill nets increased from 2010–15 at all five regions except Catfish Paradise, where numbers remained relatively the same (table 13). However, gizzard shad (*Dorosoma cepedianum*) first appeared in Topock Marsh in August 2011 (Mitch Thorson, AZFWCO, written comm., 2011) and quickly proliferated in subsequent years (fig. 26). If gizzard shad numbers are excluded from the totals, the trend of steadily increasing numbers is no longer apparent (table 13). Two game species were captured in increasing numbers throughout the marsh: striped bass (*Morone saxatilis*) had peaks in 2012, 2014, and 2015; and channel catfish numbers more than doubled in 2013–15 (fig. 26). However, largemouth bass declined steadily from 2010–15. If we look at changes during time among the five regions, the numbers of fish captured per net varies depending on species (table 13). Striped bass increased between 2010 and 2015 in the north end and near the Fire Break Canal inlet. At all five regions, channel catfish (*Ictalurus punctatus*) showed a general increase from 2010 through 2015, and the largest increases were observed at the north end, Firebreak Canal inlet, and Catfish Paradise. Largemouth bass were found in highest numbers at the north end in 2010–11 and then declined precipitously, and a similar trend was seen at Catfish Paradise, but capture numbers in the other three regions showed no clear trend. Razorback sucker, the only native fish in Topock Marsh and a federally endangered species, was reintroduced in 2010 and most frequently captured near the South Dike. Numbers of razorback suckers increased in the marsh until 2012, but declined in 2013–14, and no razorback suckers were captured in 2015 (table 13 and fig. 26).

Table 12. Macroinvertebrate taxa and number of individuals collected in Topock Marsh at each sample station on each sampling date.

[TP, sampling station; S, September 2011; O[1], October 2011; JF, January/February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F, February 2014; A, April 2014; O[4], October 2014]

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-3										TP-2										TP-6										TP-8									
	2011		2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014		
	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]
ARTHROPODA																																								
COLLEMBOLA									1																															
Sminthuridae															1																									
INSECTA																																								
Ephemeroptera																																								
Baetidae																																								
Acentrella sp.																			3																					
Caenis sp.	4	1		2	66	10	6	12	29		5	4	1	61	74	1	3	4	10		2		1	6	1		2		5		5	7	13		2	4	1		28	5
Callibaetis sp.																																					1			
Odonata																																								
Aeshnidae							1										8												1						1					
Anax sp.							2										3				1	6					2			1	1	2								
Coenagrionidae	12	16		1	3	1	6	2		1	3	4		5	13	1	12	2	1		36	6		1	1		4	2	12		4	3	1		6	3	18		6	3
Argia sp.														1																										
Ischnura sp.							1																														15			
Libellulidae					1						1						1				2																			
Heteroptera																																								
Corixidae																																								
Corixidae larvae	1	2		1					4				4	75	2		1	3	19		2		8	2									231	1	1	1			53	
Trichocorixa calva													18	3				3					6	2				2					62						2	
Hydrometridae																																								
Hydrometra sp.																													1											
Trichoptera																																								
Hydroptilidae																																								
Neotrichia sp.					2	4																																		
Oxyethira sp.					1				9		1				2										1				6											
Leptoceridae																																								
Oecetis sp.																																		2					2	
Coleoptera																																								
Hydrophilidae																																								
Berosus sp.																																							2	
Paracymus sp.																	1																							
Staphylinidae																		1																						

Table 12. Macroinvertebrate taxa and number of individuals collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station; S, September 2011; O^1, October 2011; JF, January/February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^3, October 2013; F, February 2014; A, April 2014; O^4, October 2014]

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-3										TP-2										TP-6										TP-8									
	2011		2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014			2011		2012		2013			2014		
	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4
Diptera																																								
Ceratopogonidae																																								
Bezzia/Palpomyia sp.																			1										1											
Ceratopogoninae				*2*					5						3				1						1	1														
Ceratopogon sp.																			2																					
Dasyhelea sp.																																		*1*						
Chaoboridae																																								
Chaoborus sp.																								*1*																
Chironomidae																																								
Orthocladiinae																																								
Cricotopus sp.																													1				*1*	*1*			15	1	23	
Chironomini											*1*																					*11*								
Apedilum sp.	*1*	*1*					1										10															*5*	*3*				14			
Chironomus sp.														*81*	2								*4*	*4*	5	2							*5*		2		1	92	1	
Cladopelma sp.	*3*	*1*									*5*	*2*				1					*6*	*8*			1	37	3						*1*				2			20
Cryptochironomus sp.	*1*	*1*			1			6	1					*12*				2	2	7					1		1													6
Dicrotendipes sp.	*1*	*1*		*1*			2	1				*1*					2	2			*2*	*15*			14	7							*10*	*1*						
Endochironomus sp.																									1		1		1		*14*	*108*	*2*		1		6		10	4
Goeldichironomus sp.																																					371			76
Microchironomus sp.																				3																				
Parachironomus sp.	*6*	*2*				2	17	2		3	*4*	*1*					1								1		15			8		*29*	*1*		3		61			5
Polypedilum sp.								1			*1*										*83*		*3*			1						*1*	*6*		31		7	1	1	14
Tanytarsini																																								
Cladotanytarsus sp.											*1*							3															*1*							
Tanytarsus sp.																			1						5	1							*1*		1					
Tanypodinae																																								
Ablabesmyia sp.	*5*								1										3											3										
Procladius sp.				*1*					1				*1*	*211*				1	7	19																		4	3	4
Tanypus sp.						2									1			1	10	78					2	3	2		1				*2*		1			4		1
Stratiomyidae																																								
Odontomyia/Hedriodiscus sp.																																			1					

Table 12. Macroinvertebrate taxa and number of individuals collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station; S, September 2011; O[1], October 2011; JF, January/February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F, February 2014; A, April 2014; O[4], October 2014]

TP-3

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011 S	2011 O[1]	2012 JF	2012 M	2013 Jn	2013 Jl	2013 O[3]	2014 F	2014 A	2014 O[4]
CNIDARIA										
Hydridae										
Hydra sp.					5				1	
NEMERTEA (ENOPLA)										
Prostoma sp.									2	
NEMATODA										
ENTOPROCTA					1		1			
ECTOPROCTA										
ANNELIDA										
OLIGOCHAETA										
Enchytraeidae										
Naididae	*1*				6			10	9	
Dero sp.						9				
Nais sp.										
Pristina sp.										
Slavina appendiculata						1		2	6	
Tubificidae				*1*				1		
Aulodrilus pigueti										
Branchiura sowerbyi					1					
Tubificidae without hair chaetae										
Branchiobdellida										
HIRUDINEA										
Glossiphoniidae										
Helobdella triserialis							4			
Piscicolidae										
Myzobdella lugubris										
ARTHROPODA										
OSTRACODA	*1*				5				1	
Amphipoda										
Crangonyctidae										
Crangonyx sp.										
Hyalellidae										
Hyalella azteca										

TP-2

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011 S	2011 O[1]	2012 JF	2012 M	2013 Jn	2013 Jl	2013 O[3]	2014 F	2014 A	2014 O[4]
CNIDARIA										
Hydridae										
Hydra sp.										
NEMERTEA (ENOPLA)										
Prostoma sp.				*3*	3				2	
NEMATODA									1	
ENTOPROCTA										
ECTOPROCTA										
ANNELIDA										
OLIGOCHAETA										
Enchytraeidae							1			
Naididae	*9*			*4*					4	
Dero sp.					46				81	62
Nais sp.					23	1				
Pristina sp.					1					
Slavina appendiculata					58			1		
Tubificidae				*4*	4			4	31	
Aulodrilus pigueti										2
Branchiura sowerbyi					1			7		22
Tubificidae without hair chaetae										37
Branchiobdellida					7					
HIRUDINEA										
Glossiphoniidae										
Helobdella triserialis							6			
Piscicolidae										
Myzobdella lugubris										
ARTHROPODA										
OSTRACODA				*4*	6		2			
Amphipoda										
Crangonyctidae										
Crangonyx sp.									3	
Hyalellidae										
Hyalella azteca										

TP-6

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011 S	2011 O[1]	2012 JF	2012 M	2013 Jn	2013 Jl	2013 O[3]	2014 F	2014 A	2014 O[4]
CNIDARIA										
Hydridae										
Hydra sp.									11	
NEMERTEA (ENOPLA)										
Prostoma sp.			*1*				2		3	
NEMATODA									1	
ENTOPROCTA						1				
ECTOPROCTA										
ANNELIDA										
OLIGOCHAETA										
Enchytraeidae										
Naididae	*6*			*2*					13	
Dero sp.					28	5	1		6	
Nais sp.					3					
Pristina sp.										
Slavina appendiculata									20	
Tubificidae	*1*			*5*	2	1		6	9	
Aulodrilus pigueti										
Branchiura sowerbyi										
Tubificidae without hair chaetae										
Branchiobdellida										
HIRUDINEA										
Glossiphoniidae										
Helobdella triserialis										
Piscicolidae										
Myzobdella lugubris										
ARTHROPODA										
OSTRACODA									11	
Amphipoda										
Crangonyctidae										
Crangonyx sp.										
Hyalellidae										
Hyalella azteca										

TP-8

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011 S	2011 O[1]	2012 JF	2012 M	2013 Jn	2013 Jl	2013 O[3]	2014 F	2014 A	2014 O[4]
CNIDARIA										
Hydridae										
Hydra sp.										
NEMERTEA (ENOPLA)										
Prostoma sp.					2	2				
NEMATODA										
ENTOPROCTA								1		
ECTOPROCTA							1			
ANNELIDA										
OLIGOCHAETA										
Enchytraeidae										
Naididae			*2*	*2*			32		7	
Dero sp.					26	8	1	7	2	269
Nais sp.										
Pristina sp.					2					
Slavina appendiculata										
Tubificidae		*1*	*5*	*2*	18	2	8	146	2	
Aulodrilus pigueti										1
Branchiura sowerbyi										
Tubificidae without hair chaetae										14
Branchiobdellida										
HIRUDINEA										
Glossiphoniidae										
Helobdella triserialis										
Piscicolidae										
Myzobdella lugubris									2	
ARTHROPODA										
OSTRACODA			*1*	*3*	9		2		28	
Amphipoda										
Crangonyctidae										
Crangonyx sp.										
Hyalellidae										
Hyalella azteca			*4*		9	1	26		33	

Table 12. Macroinvertebrate taxa and number of individuals collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station; S, September 2011; O[1], October 2011; JF, January/February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O[3], October 2013; F, February 2014; A, April 2014; O[4], October 2014]

TP-3

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011		2012		2013			2014		
	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]
Decapoda										
Cambaridae										
Procambarus clarkii[b,c]	2	3								
Palaemonidae										
Palaemonetes sp.[b]	17	8	4	9				1		9
ACARI										
Arrenuridae (Arrenurus sp.)										
Limnesiidae										
Limnesia sp.										
Orbatidae										
Hydrozetes sp.										
Pionidae										
Piona sp.					1	1		2		
Sperchonidae										
Sperchon sp.					4	5		10		
MOLLUSCA										
GASTROPODA										
Ancylidae (Ferrissia sp.*)*					2					
Lymnaidae										
Physidae										
Physa sp.	17	19		7	8	18	68	4	7	
Planorbidae (Gyraulus sp.*)*					2		1			
BIVALVIA										
Corbiculidae										
Corbicula sp.			2	56	38	1		9	2	
Dreissenidae										
Dreissena rostriformis bugensis[b]					1			3		

TP-2

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011		2012		2013			2014		
	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]
Decapoda										
Cambaridae										
Procambarus clarkii[b,c]		1					1			
Palaemonidae										
Palaemonetes sp.[b]	12	4			4		1			
ACARI										
Arrenuridae (Arrenurus sp.)			5							
Limnesiidae										
Limnesia sp.										
Orbatidae										
Hydrozetes sp.					1					
Pionidae										
Piona sp.					12					
Sperchonidae										
Sperchon sp.					2	2		1		
MOLLUSCA										
GASTROPODA										
Ancylidae (Ferrissia sp.*)*					3				2	18
Lymnaidae			1							
Physidae										
Physa sp.	12	61	2	9	28	4	122	11	4	21
Planorbidae (Gyraulus sp.*)*					19					2
BIVALVIA										
Corbiculidae										
Corbicula sp.			1	82		3		1	1	7
Dreissenidae										
Dreissena rostriformis bugensis[b]			1	18	3	6		6		

TP-6

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011		2012		2013			2014		
	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]
Decapoda										
Cambaridae										
Procambarus clarkii[b,c]	3	1								
Palaemonidae										
Palaemonetes sp.[b]	10	1			1	1	3		1	1
ACARI					2			1	2	
Arrenuridae (Arrenurus sp.)										
Limnesiidae										
Limnesia sp.										
Orbatidae										
Hydrozetes sp.										
Pionidae										
Piona sp.									4	
Sperchonidae										
Sperchon sp.					1			1		
MOLLUSCA										
GASTROPODA										
Ancylidae (Ferrissia sp.*)*				1	30			2		
Lymnaidae										
Physidae										
Physa sp.	54	223	7	2	95	20	85	4	5	4
Planorbidae (Gyraulus sp.*)*			1		4			2		
BIVALVIA										
Corbiculidae										
Corbicula sp.	3	1	2		2	1				
Dreissenidae										
Dreissena rostriformis bugensis[b]						1				

TP-8

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	2011		2012		2013			2014		
	S	O[1]	JF	M	Jn	Jl	O[3]	F	A	O[4]
Decapoda										
Cambaridae										
Procambarus clarkii[b,c]				1						
Palaemonidae										
Palaemonetes sp.[b]	8	1	16	8	4		400	1	3	3
ACARI				2					1	
Arrenuridae (Arrenurus sp.)										
Limnesiidae										
Limnesia sp.									3	
Orbatidae										
Hydrozetes sp.										
Pionidae										
Piona sp.										
Sperchonidae										
Sperchon sp.										
MOLLUSCA										
GASTROPODA										
Ancylidae (Ferrissia sp.*)*					6	1		1		
Lymnaidae										
Physidae										
Physa sp.	14	40	10	2	2	22	475	1	1	2
Planorbidae (Gyraulus sp.*)*		9	2			2	8			
BIVALVIA										
Corbiculidae										
Corbicula sp.					1					
Dreissenidae										
Dreissena rostriformis bugensis[b]					1					

Table 12. Macroinvertebrate taxa and number of individuals collected in Topock Marsh at each sample station on each sampling date.—Continued

[TP, sampling station; S, September 2011; O^1, October 2011; JF, January/February 2012; M, March 2012; Jn, June 2013; Jl, July 2013; O^3, October 2013; F, February 2014; A, April 2014; O^4, October 2014]

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-3									
	2011		2012		2013			2014		
	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4
Total number of taxa by date and location	14	11	2	9	18	11	12	15	15	3
Total number of organisms by date and location	72	55	6	79	148	54	110	66	79	13
Maximum individuals in a given taxa:	17	19	4	56	66	18	68	12	29	9
Mean organisms by sampling station										68

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-2									
	2011		2012		2013			2014		
	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4
Total number of taxa by date and location	12	8	9	16	25	8	16	17	21	12
Total number of organisms by date and location	55	78	34	575	319	19	175	53	189	278
Maximum individuals in a given taxa:	12	61	18	211	74	6	122	11	81	78
Mean organisms by sampling station										178

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-6									
	2011		2012		2013			2014		
	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4
Total number of taxa by date and location	14	8	9	10	22	14	12	8	21	5
Total number of organisms by date and location	211	261	33	26	202	82	121	20	115	17
Maximum individuals in a given taxa:	83	223	8	6	95	37	85	6	20	8
Mean organisms by sampling station										109

PHYLUM; CLASS or SUBCLASS; Order or Suborder; Family; Subfamily or Tribe; Genus species[a]	TP-8									
	2011		2012		2013			2014		
	S	O^1	JF	M	Jn	Jl	O^3	F	A	O^4
Total number of taxa by date and location	6	12	22	12	22	10	21	11	21	15
Total number of organisms by date and location	46	217	380	26	130	46	1465	259	213	427
Maximum individuals in a given taxa:	14	108	231	8	31	22	475	146	53	269
Mean organisms by sampling station										321

[a]The orders do not necessarily belong to the class that they are listed under.

[b]Nonnative species.

[c]Data for *P. clarkii* are from crayfish traps set in 2011–2013, not from D-net sweeps.

Species richness 2011–2012: 41

Species richness 2013–2014: 72

Species richness: Total number of taxa occurring in Topock during 2011–2014 = 78

Table 13. Summary of fish captured per net by Arizona Game and Fish Department using experimental gill nets each February from 2010 to 2015.

[Locations where gill nets were set are divided into five regions within Topock Marsh and illustrated in figures 25*A* and 25*B*. NE, North End; FB, Fire Break Canal; BO, Beal Lake Outlet; CF, Catfish Paradise; SD, South Dike; AGFD, Arizona Game and Fish Department]

Year	Region[1]	Number of gill nets set	Number of fish captured per net in each region[1]											
			Razorback sucker	Gizzard shad	Threadfin shad	Channel catfish	Yellow bullhead	Largemouth bass	Striped bass	Sunfish species[2]	Black crappie	Carp and goldfish	Total number of fish in region	Total fish minus gizzard shad
2010	NE	3	0.0	0.0	0.0	4.0	1.3	15.3	2.0	1.0	0.0	5.3	28.9	28.9
2011	NE	3	1.7	0.0	0.3	4.3	1.0	10.3	0.0	0.7	3.0	2.7	24.0	24.0
2012	NE	1	1.0	1.0	0.0	6.0	1.0	5.0	6.0	0.0	3.0	2.0	25.0	24.0
2013	NE	1	0.0	1.0	0.0	15.0	4.0	4.0	0.0	0.0	2.0	3.0	29.0	28.0
2014	NE	2	1.5	10.0	0.0	19.5	1.0	3.0	7.5	0.0	1.0	1.0	44.5	34.5
2015	NE	2	0.0	36.0	0.5	4.5	0.0	0.5	8.5	0.0	2.0	1.0	53.0	17.0
2010	FB	2	0.5	0.0	2.0	3.0	1.0	2.5	0.5	0.0	0.0	5.0	14.5	14.5
2011	FB	2	0.0	0.0	0.0	2.5	2.0	2.0	0.0	0.5	3.0	2.5	12.5	12.5
2012	FB	4	2.3	1.3	0.5	4.0	0.8	2.0	6.3	0.0	1.0	1.5	19.7	18.4
2013	FB	4	2.5	1.3	0.0	12.3	3.0	3.5	1.3	0.5	0.8	4.8	30.0	28.7
2014	FB	3	1.3	19.7	0.0	6.7	2.0	1.7	14.7	0.3	1.3	1.0	48.7	29.0
2015	FB	2	0.0	39.5	0.5	12.0	3.0	0.0	17.5	0.0	0.5	1.0	74.0	34.5
2010	BO	1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	6.0	8.0	8.0
2011	BO	0	No nets set in this region											
2012	BO	2	0.0	0.0	0.0	0.5	0.0	1.0	0.0	1.0	0.5	3.5	6.5	6.5
2013	BO	3	0.7	3.3	0.0	1.0	0.0	1.0	0.3	0.3	0.0	1.7	8.3	5.0
2014	BO	2	0.0	2.5	0.0	2.0	1.0	2.5	0.0	0.5	0.5	5.0	14.0	11.5
2015	BO	2	0.0	20.0	0.0	4.0	0.5	0.5	0.5	0.0	0.5	0.0	26.0	6.0
2010	CF	3	1.3	0.0	1.7	2.7	1.0	5.3	0.0	2.0	2.7	11.0	27.7	27.7
2011	CF	4	1.0	0.0	0.0	1.5	0.0	2.3	0.0	0.3	2.5	3.0	10.6	10.6
2012	CF	2	1.0	2.0	0.0	1.0	0.0	3.5	1.0	0.0	3.5	2.0	14.0	12.0
2013	CF	1	1.0	7.0	0.0	3.0	3.0	1.0	0.0	0.0	1.0	1.0	17.0	10.0
2014	CF	2	1.5	21.5	0.0	6.5	0.0	1.5	0.0	0.0	1.0	2.0	34.0	12.5
2015	CF	2	0.0	9.5	0.0	11.0	1.0	2.0	0.0	1.5	1.0	1.0	27.0	17.5
2010	SD	1	8.0	0.0	0.0	3.0	0.0	1.0	0.0	2.0	5.0	21.0	40.0	40.0
2011	SD	1	8.0	0.0	1.0	1.0	0.0	2.0	1.0	0.0	0.0	5.0	18.0	18.0
2012	SD	1	10.0	6.0	0.0	1.0	0.0	1.0	11.0	0.0	3.0	3.0	35.0	29.0
2013	SD	1	2.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.0	7.0	6.0
2014	SD	1	4.0	38.0	0.0	5.0	1.0	4.0	0.0	0.0	0.0	2.0	54.0	16.0
2015	SD	1	0.0	36.0	11.0	7.0	0.0	3.0	2.0	0.0	2.0	0.0	61.0	25.0

[1]Regions where AGFD set gill nets in Topock Marsh: NE = North End ; FB = Fire Break Canal; BO = Beal Lake Outlet; CF = Catfish Paradise; SD = South Dike.

[2]Sunfish species included bluegill, green sunfish, and redear.

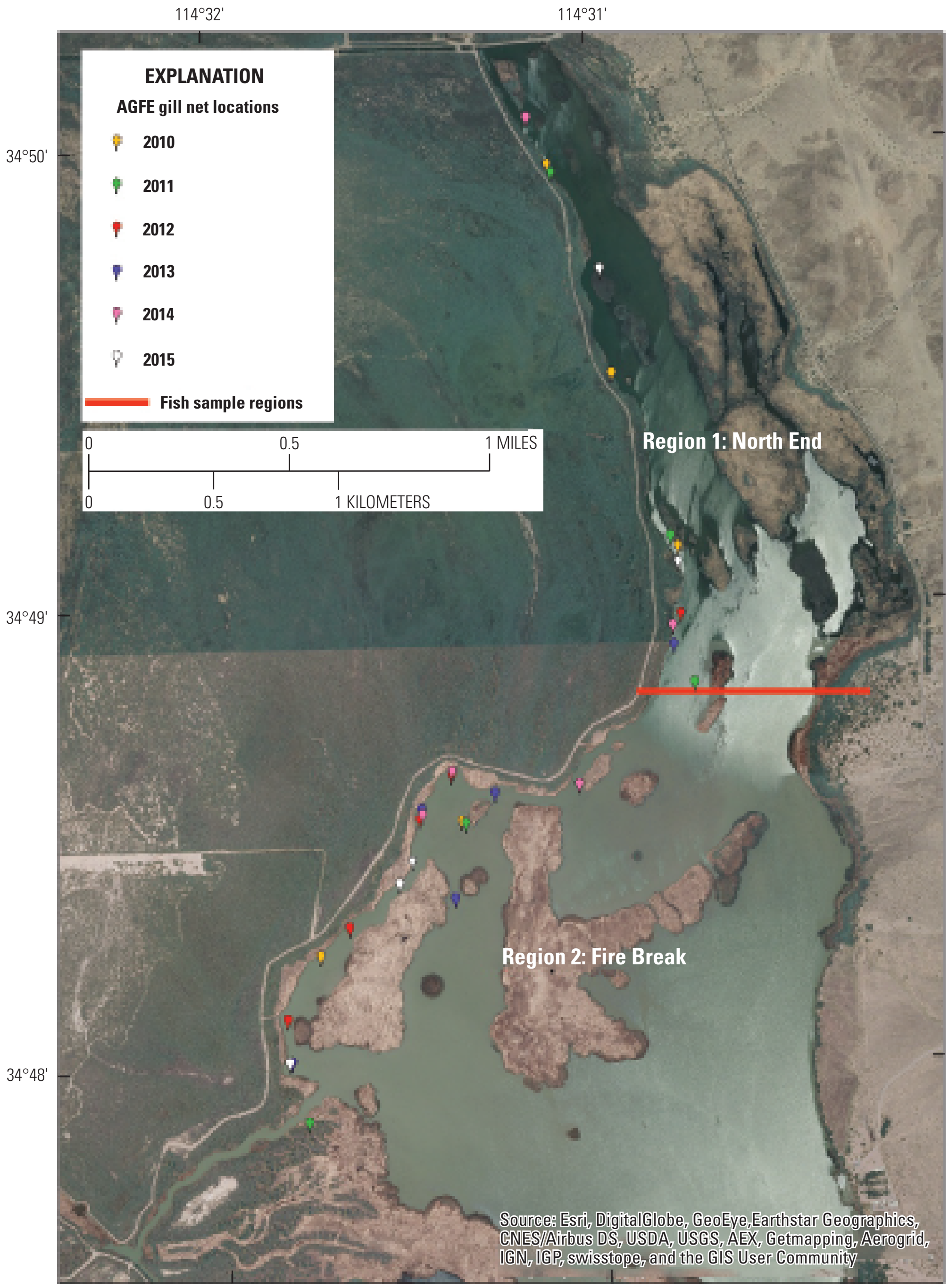

Figure 25*A*. Northern portion of Topock Marsh showing Arizona Game and Fish Department's (AGFD's) gill net locations, 2010–2015. (See table 13 for fish numbers captured per net in each region by year).

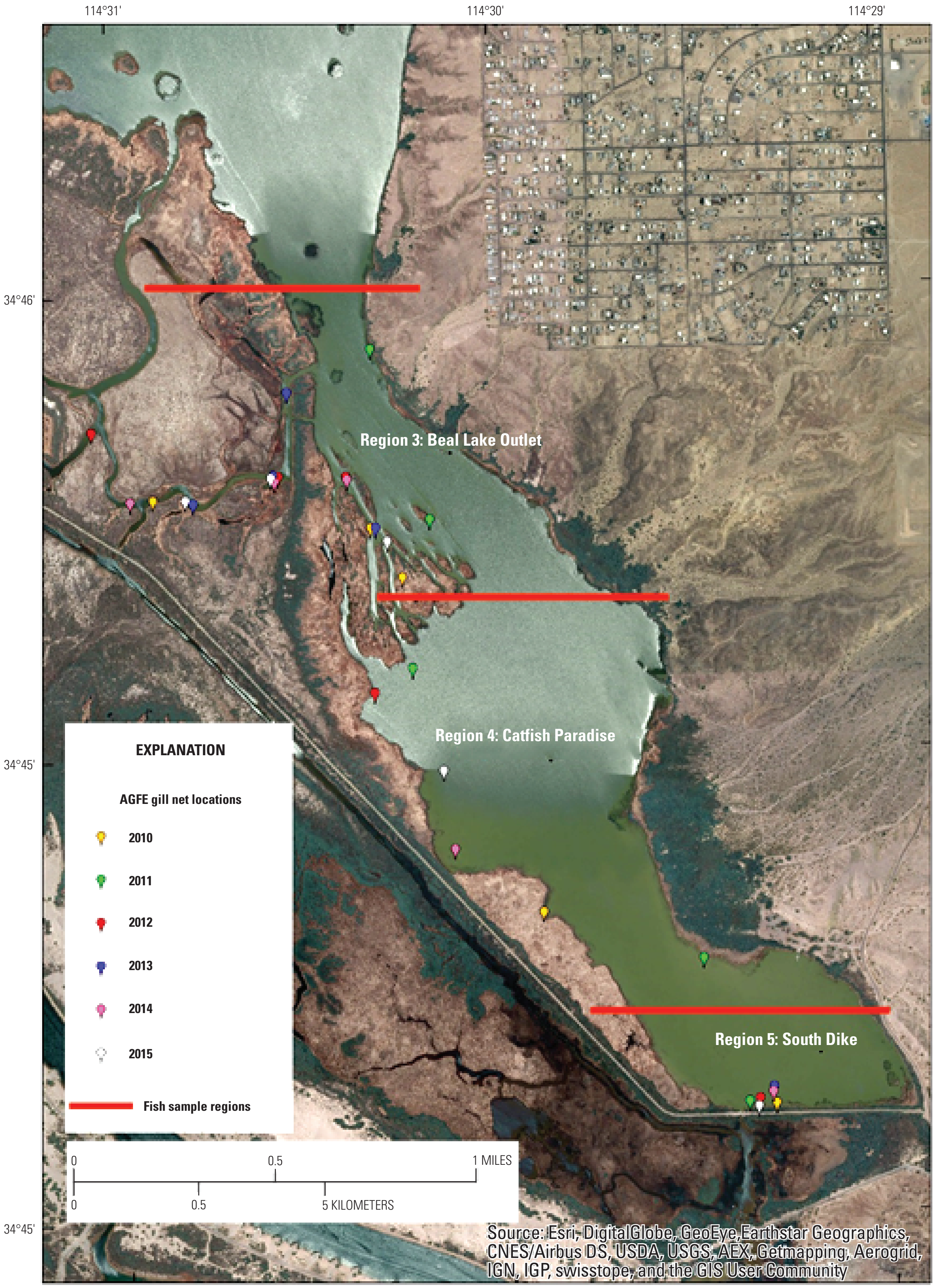

Figure 25*B*. Southern portion of Topock Marsh showing AGFD's gill net locations, 2010–2015. (See table 13 for fish numbers captured per net in each region by year).

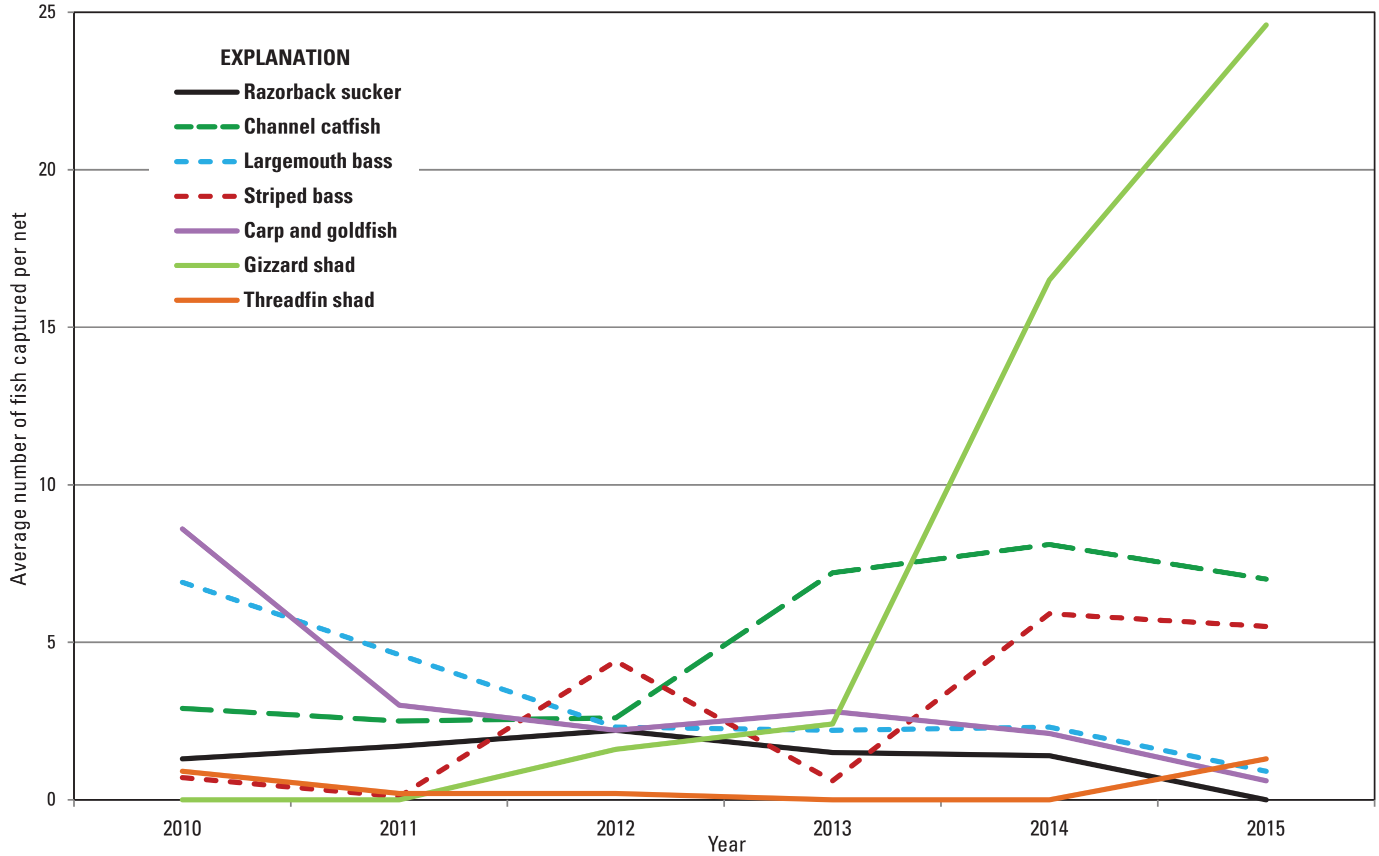

Figure 26. Average number of fish captured per gill net per year in Topock Marsh by species. Data were provided by Arizona Game and Fish Department.

Discussion

The central question throughout this study was how do waterflows, water conditions, and the Havasu NWR's associated water management decisions affect multiple indicators of ecological conditions and ecological change in the Topock Marsh ecosystem? For the initial 2011–12 investigation, the marsh was evaluated under low waterflow conditions. For 2013–14, the marsh was evaluated under higher waterflow conditions. This report discusses the study's findings, and tries to relate various components and describe potential mechanisms. Detailed data summarized within this report are available in the Topock Marsh Water and Resource Management DSS for use as Excel spreadsheets that provide specific biotic and abiotic information under low and high hydrologic conditions (Holmquist-Johnson and others, 2016).

Water-Quality Characteristics

Physicochemistry

By recording depth profiles (figs. 4, 6, 8, 10, and 13) and diurnal tracks (figs. 5, 7, 9, 11, and 14) of various parameters from each of the 4 sampling stations in Topock Marsh during 11 sampling dates, a wide range of seasonal data have been accumulated. Much of this physicochemistry data followed well-defined seasonal, daily, and (or) spatial patterns. However, other data were directly related to waterflow and elevation effects.

Water temperature extremes ranging from a high of 35.8 °C (96.4 °F) to a low of 5.2 °C (41.4 °F) (fig. 4) during the sampling trips were indicative of seasonal patterns. Water temperatures at the surface during September 2011, June and July 2013, April 2014, and September 2014, dropped with depth at TP-2 (figs. 4*Ab* and 4*Bb*), showing evidence of colder Colorado River water entering the marsh at that location. For comparison, temperatures on the river downstream of Needles Bridge averaged 20.9 °C (69.6 °F) during the 2013 summer (Scott O'Meara, Bureau of Reclamation, unpub. data, 2014). Cooler months did not have as large a temperature difference between the marsh and the river, and inflow from the Fire Break Canal was minimal during the winter months, so the mixture of marsh and river water was less evident (fig. 2*A*).

Diurnal water temperature fluctuations followed normal well-defined seasonal, daily, and spatial patterns as well. As with the depth profile data, the lower diurnal water temperatures at TP-2 indicated cooler Colorado River water entering the marsh at that location during the warmer months of 2013 and 2014 (fig. 5*B*).

Specific conductivity values and their variation during the study period, in addition to the variations in water temperature, provide clues as to what was happening within Topock Marsh in response to different waterflow conditions. During the initial sampling trip (July 2011), SC within Topock Marsh was highest at TP-3 and TP-2, the most upstream sampling stations, and lowest at TP-8 (figs. 6*A* and 7*A*). However, by September 2011, SC concentrations at TP-3 and TP-2 decreased substantially compared to the July 2011 values (fig. 7*A*) and concentrations at TP-8 increased (fig. 6*Ad*). The differences most likely were due to the influence of Colorado River water entering the marsh during September, and again later in October, from the Fire Break Canal (fig. 2*A*). Likewise, during the February 1, 2012, sampling event, river water with lower SC was flowing in from all three inlets: Inlet Canal, Fire Break Canal, and Farm Ditch Canal (fig. 2*A*). At TP-2, the deepest sampling station, the warmer river water flowed past our sampling station near the surface and the cooler marsh water containing higher SC concentrations remained nearer to the marsh floor (fig. 6*Ab*). However, after 1½ months of constant daily inflow from the Topock Inlet and Fire Break Canals and very strong winds between January and March (up to 91.1 km/h (56.0 mi/h) on March 6) (fig. 3*B*), the water chemistry in March was thoroughly mixed throughout the water column at both TP-3 and TP-2 and SCs at those locations were very similar (figs. 6*Aa*, 6*Ab* and 7*A*).

The pattern of spatial variability in SC within the marsh during 2013 and 2014 differed from the 2011–12 sampling period because of the more consistent inflow from the Colorado River through the Fire Break Canal and the closure of the Inlet Canal (fig. 2*A*). Temperature depth profiles confirmed that cooler, fresher water entered the marsh near TP-2 and slightly lowered SC values during June and July 2013 and April 2014 (fig. 6*Bb*). The diurnal tracks in figure 7 illustrate how SC decreased from 0.076 m^3/s (2.7 ft^3/s) to 0.368 m^3/s (13 ft^3/s) as inflow ramped up during the February 2014 sampling week. By mid-March 2014, Fire Break Canal inflows were consistently maintained above 2.0 m^3/s (70 ft^3/s) and these inflows continued through the April 2014 sampling trip. Not only did these inflows freshen the water at TP-2, but they appear to have freshened the water as far upstream as TP-3 (fig. 7*B*) as indicated by the decreasing SC concentrations (table 4 and fig. 6*Ba*). Likewise, inflow through the Farm Ditch Canal helped freshen water at TP-6 (fig. 6*Bc*). Water at TP-8 was not affected by the fresher water by April 2014, but by the September/October 2014 sampling trip, the SC decreased from an average of 2,020 µS/cm (1,295 ppm) to 1,810 µS/cm (1,160 ppm) (fig. 6*Bd*).

October pH values recorded at TP-6 and TP-8 in 2011, and at all four sampling stations in 2013 and 2014, were consistently higher than those recorded during the other sampling periods as shown by the depth profiles (fig. 8) and diurnal fluctuation graphs (fig. 9). The higher values and larger fluctuations in pH during 2013 and 2014 were especially pronounced and were most likely due to diurnal dynamics in photosynthesis and respiration by the dense SAV (Cronk and Fennessy, 2001; Kadlec and Wallace, 2009) at TP-3 and TP-6 (fig. 9*B*) and the high density and biovolume of phytoplankton (fig. 23) at TP-8. Inversely, pH values were lower throughout the marsh in February 2014 (fig. 9) when virtually no SAV and somewhat less phytoplankton was present. Similar seasonal shifts in pH reported by Guay (2001) were also likely due to the seasonal changes in SAV. Otherwise, pH ranged from 7.58 to 9.08 throughout the study period.

Dissolved oxygen concentrations varied temporally, seasonally, and spatially within the marsh (fig. 10). Observed diurnal variation (fig. 11) was most likely due to oxygen production during photosynthesis by the SAV and phytoplankton during daylight, and the lack of photosynthesis at night (Reddy and DeLaune, 2008). Plant coverage was denser in September and October every year, so DO swings tended to be larger during that time. Additionally, DO concentrations at all locations were higher during the cooler months of December through March each year (fig. 3), thus illustrating the typical inverse relationship between DO and temperature (Kadlec and Wallace, 2009). Differences in DO between the sampling stations are most likely due to variations in plant and phytoplankton densities, wind patterns, and proximity to the inflow of fresh Colorado River water (Chui and Jirka, 2003). In fact, diurnal swings in DO at TP-2 were smaller than at other sites, which is likely due to the 2.5-m (8.2-ft) deep channel at that sampling location not being conducive to SAV growth. However, the increasing DO values at TP-2, recorded by the MiniSonde units deployed at the site (fig. 11) during April and September/October 2014 were unexpected. It is possible the DO probes on the MiniSonde units malfunctioned, even though they were different units each time and both units were calibrated prior to deployment. Water inflow was high during the April 2014 sampling trip (an average of 3.52 m^3/s [124.18 ft^3/s]), but was not as high during the September/October 2014 sampling trip (an average of 0.889 m^3/s [31.37 ft^3/s]). The most important conclusion regarding DO within Topock Marsh is that all locations had DO concentrations well above the minimum threshold of 3.0 mg/L, which is established as the one-day criteria for “other life stages” of warm water fish by the U.S. Environmental Protection Agency (1986a).

Water clarity varied spatially, most likely because of local differences in water depth, sediment texture, SAV abundance, and disturbance of the underlying sediments from wind, fish, birds, or motor boat activity (tables 4 and 6; and figs. 12, 13, and 14). Of course, most of these influences were seasonal as well. TP-8 is located near the end of the marsh in an area that is very exposed to winds and motor boat traffic and is used by abundant wildlife (fish and waterfowl), which stir up the sediments and add to the nutrient load (Andersen and others, 2003). As further evidence of the turbid conditions, TSS concentrations were consistently higher (table 4) and Secchi disk readings were consistently lower (fig. 13) at TP-8 compared to the other sites throughout 2013 and 2014. Examining the water-quality data throughout the sampling periods, samples collected in 2011–12 lead us to conclude that much of the turbidity throughout the marsh was due to the suspension of the autochthonous sediment. This conclusion, which is based in part on the lower percentage organic N to total nitrogen concentrations (table 4) and the "very heavy sediment" comment by the phytoplankton technician in regards to the 2012 samples from TP-6, corroborates Guay's (2001) findings. In 2013 and 2014, on the other hand, samples collected at TP-8 contained high chlorophyll *a* concentrations (fig. 15), high phytoplankton densities and biovolumes (fig. 23) and high organic-N concentrations. Thus, we conclude that, in 2013 and 2014, dense phytoplankton was primarily responsible for the higher turbidity at TP-8.

Inversely, turbidity was lower and water clarity was higher at the upstream stations in 2013–14. Turbidity values were lower at TP-2 (fig. 12), where fresh Colorado River water enters one of the deepest sections of the marsh through a concrete-lined canal, and at TP-3 and TP-6, where dense SAV was present to trap suspended sediments and hold the soft loamy sand, clay loam, and silty clay loam substrate in place (table 6). Alanen (1998) observed that, in general, areas in Topock Marsh that had the lowest turbidity were associated with high SAV coverage, and areas with high turbidity contained less SAV coverage. However, Alanen (1998) reported much lower mean turbidity values than the values reported in this report. Alanen reported yearly grand means of 9.5 and 18.4 NTUs for 1996 and 1997, respectively, compared to our yearly grand means throughout the marsh that ranged between 39.3 and 62.4 NTUs (table 4, surface turbidity values). The highest turbidity Alanen reported was 29.9 NTUs, which was measured in the Upper Goose Lake, the open area between TP-1 and TP-7. Guay (2001) found turbid conditions ranging between 20 and 50 NTUs and averaging about 25 NTUs; this value is 36 percent lower than our lowest yearly mean results.

Chlorophyll *a*, Nutrients, Major Ions, and Trace Elements

During low-flow conditions in July 2011, chlorophyll *a* concentrations were moderately high throughout Topock Marsh; however, once inflow resumed from the Colorado River, water containing lower chlorophyll *a* concentrations pushed the higher concentrations downstream where they concentrated at TP-8, the most downstream sampling station. Following the completion of the Fire Break Canal in January 2012, the lowest chlorophyll *a* concentrations consistently occurred at TP-2, but one notable exception occurred in September/October 2014 at TP-6 where spiny naiad was very dense (table 12) and water clarity was the greatest (fig. 13).

Mirroring the downstream movement of the chlorophyll *a* concentrations, surface water samples from TP-8 consistently contained at least twice the TN, Org-N, and TP concentrations as the other sampling stations (fig. 16). The high average percentage of Org-N to TN (>80 percent) throughout the 4 years of sampling (table 4), and even higher percentages throughout the springs and summers (≥92 percent), provides evidence that the majority of TN was likely due to the phytoplankton in the water column (See figs. 15 and 23 and the Phytoplankton, Zooplankton, and Aquatic Macroinvertebrates section of this report for more information.). Likewise, lower percentages of Org-N to TN measured at TP-2 likely were due to relatively less phytoplankton in the fresh water inflow from the Colorado River, which contained higher mean concentrations of inorganic nitrogen (0.35 mg/L) (Scott O'Meara, Bureau of Reclamation, unpub. data, 2014).

Stiff diagrams for 2011 (fig. 17), 2013 (fig. 18), and 2014 (fig. 19) were used to compare the ionic composition of the water from the four sampling stations and the Colorado River water (inset in diagram *B*. on figs. 18 and 19) through time. Water at TP-2 was clearly the most similar to the river water during each year (figs. 17, 18, and 19). Water at TP-8, the furthest sampling station downstream of the Fire Break Canal and the Farm Ditch Canal, was the least similar to river water in 2013 and 2014. Thus, these diagrams illustrate the gradual change in ionic composition as the water moved further downstream and away from where the river water entered the marsh.

Results of analyses for elements of concern are listed in table 5. Most values during 2013–14 were similar to, or less than, 2011 values, presumably due to dilution from the additional waterflow in 2013–14. The exceptions are mean As concentrations in both 2013 and 2014 and Mn concentrations in 2014 at TP-8, which were higher than in previous years. In fact, concentrations of As, B, Cr, fluoride, Fe, Mn, and lead were higher at TP-8 than at the other sampling stations because dissolved elements concentrated at the terminus of the system. The replicate samples collected from TP-6 contained markedly lower concentrations of Fe, Mn, lead, and Se during September/October 2014. SAV was so dense at TP-6 in fall 2014 that it is likely that plants played a role in decreasing elemental concentrations by taking up more elements and (or) providing a filtering mechanism that allowed dissolved solids to fall out of the water column into the sediment below (Cronk and Fennessy, 2001). Note the lower TSS concentrations (table 4) at TP-6 throughout the study period. Concentrations of elements of concern for wildlife (that is, As, Hg, Se, and Cr) in water samples were below State and Federal toxicity standards (table 5) (Eisler, 1988; Arizona Department of Environmental Quality [ADEQ], 2009) for aquatic wildlife.

Long-Term Water Chemistry

An informal review of the long-term water chemistry data displayed in appendix 1 indicates that the values observed during the study period were not unusual. There was a fairly consistent trend in SC from 1983 to April 2015 of the measured parameters peaking during the winter prior to spring water releases from Davis Dam (fig. 20). Between June 1994 and June 2003, fewer extremes (highs and lows) were recorded, but the SC extremes resumed in late 2003 when SC generally increased through January 2011 (fig. 20) as Guay (2001) predicted if water management remained the same. After the Fire Break Canal became operational, average SC values in the marsh were only slightly higher (1.12 times) than values reported by Guay (2001) for 1995–1998. In fact, SC decreased overall within the marsh from 2,237 µS/cm (1,434 ppm) in

January 2012 to 1,937 µS/cm (1,242 ppm) in January 2015 (app. 1 and fig. 20). Water-quality monitoring would need to be continued to verify this trend. These data, and all the historical water chemistry data, provide valuable information to help predict future water quality and wildlife habitat changes caused by various water management scenarios, which are in turn tied to the capacity of the Havasu NWR's water-related infrastructure.

Sediment Chemistry

A great deal of variation was found among sediment collected from the four sampling stations in 2011, 2013, and 2014 (table 6). However, variations were not unexpected since soil texture, water chemistry, and the presence or absence of vegetation differed between sampling locations, as well as between seasons. Although these results represent a wide variation in sediments throughout the marsh, no potential problems or toxicity issues were noted, with the exception of a slightly elevated As concentration at TP-2 in October 2014. However, there were no signs of bioaccumulation evident during the study, and the remaining samples contained concentrations of As, Cr, Hg, and Se below established threshold effects for wildlife (MacDonald and others, 2000; Lemly, 2002).

Alanen (1998) assumed that nutrients in the water were less important to spiny naiad growth than nutrients in the sediment because the roots of this plant comprise an unusually large proportion (30 percent) of total plant weight (Waisel and Agami, 1983). Although rooted, submerged plants can take up DO, carbon dioxide, and micronutrients from the water column, the majority of nutrients are acquired from the sediment (Barko and Smart, 1981; Cronk and Fennessy, 2001). Ammonium nitrogen and nitrate nitrogen concentrations in the sediments produced by decomposer microbes from senesced plant litter may be most important to aquatic plant productivity, as microbes decompose the plant litter annually (Vymazal, 1995). It was determined that sediment nutrients were highest at TP-6 where SAV coverage was also highest on all sampling occasions (tables 6 and 8).

Plant Chemistry

Chemical analyses of California bulrush collected at each sampling station in July 2013, and of spiny naiad and Eurasian watermilfoil collected in October 2014, indicated large variations between plant species and seasons (table 7), so direct analytical comparisons between the two sampling events are not appropriate. The culms (specialized stems) of California bulrush, an emergent plant rooted in the soil, stand upright and thus contain lignin for aerial support. The submerged plants, spiny naiad and Eurasian watermilfoil, are also rooted in the soil but their stems and leaves are soft (lacking lignin) and they spend their entire life cycle under water (Cronk and Fennessy, 2001). Hence, because of their differing morphologies, the chemical makeup of the plant types is different. In addition, the chemical makeup of these plants in summer would be different from that in the fall when plants generally contain more nutrients in their storage tissues (Salisbury and Ross, 1969). The differences in the concentration of some elements in the same plant species between sampling stations may have been due to variations in the sediment or water chemistry, or possibly to the sites' proximity to Colorado River influxes. For example, aluminum, Cu, and Fe concentrations were higher in plant material collected near TP-2 than in the plant material collected at the other locations. Suspension solids and algae in the water column can settle out and accumulate on leaf surfaces of SAV and be collected along with the vegetation for analyses, even with careful rinsing, thus, increasing the amount of nutrients and (or) other elements found (Vymazal, 1995; Kabata-Pendias and Pendias, 2001). Upright culms do not accumulate as much inorganic or organic material through settling of solids and algae. Even with these differences, it is interesting to note the variation between the emergent and submerged plants and to compare the chemical makeup between sampling stations. The most notable conclusion from the plant chemistry data is that concentrations of As, Cr, Hg, and Se were all below established threshold effects on wildlife (MacDonald and others, 2000; Lemly, 2002; ADEQ, 2009).

Biological Characteristics

Aquatic Vegetation

The predominant SAV in Topock Marsh during the 2011–14 study period was spiny naiad with smaller quantities and occurrences of sago pondweed. The study found that temperature affected the coverage success of the species (for example, virtually no SAV was observed from January to March). In addition, turbidity and water depth were important in explaining their coverage success (fig. 22), and both species achieved maximum coverage during October each year (table 8). Spiny naiad was particularly abundant in shallow water (0.60–0.76 m [2.0–2.5 ft] depth) and somewhat protected areas where water clarity was relatively high (such as, turbidity ≤39 NTUs). Sago pondweed occurred in low to moderate amounts in clear, typically shallower areas (0.30–0.46 m [1.0–1.5 ft] depth). The microalgae, chara, occurred infrequently during this time and in small assemblages throughout the marsh (table 8).

Eurasian watermilfoil, an invasive SAV, was first noted in early 2012 near TP-2 at the mouth of the Fire Break Canal. By October 2014, it was well established and thriving around that same location, as well as where Colorado River water enters the marsh through the Farm Ditch Canal (fig. 1). Because Eurasian watermilfoil has been common in the Colorado River for a number of years (U.S. Geological Survey, 2016c), it was not unexpected to see the plant in Topock Marsh once Fire Break Canal created a new connection directly from the river.

SAV was abundant in shallow, protected areas in 2011, but very little SAV was observed during 2011–12 in the shallow, exposed areas in the center of the marsh (that is, the areas between TP-1 and TP-7 and east of both TP-5 and TP-6) (fig. 1). During that period, it was evident that winds had stirred up sediments through wave action, causing highly turbid conditions in the shallow, exposed areas that could otherwise support SAV. Guay (2001) reported similar observations and concluded that Topock Marsh was generally too turbid for submerged plant growth (Vymazal, 1995). Alanen (1998) agreed, stating that light availability, as a function of turbidity, seemed to have the greatest influence on SAV distribution and abundance. Hence, both Guay (2001) and Alanen (1998) concluded that light availability was probably the limiting factor controlling SAV distribution in the marsh. During our subsequent sampling in 2013 and 2014, we found that SAV abundance was higher when turbidity was lower. Therefore, based on our work in Topock Marsh (fig. 22 and table 8), published literature (Sand-Jensen and Borum, 1991; Cronk and Fennessy, 2001), and personal observations at other turbid southwestern United States' wetland systems, we agree with Guay's (2001) and Alanen's (1998) conclusion.

Assuming that light availability through the water column and water depth are related, Alanen (1998) further predicted that SAV biomass would be more abundant during the growing season if water levels were kept below a maximum target WSE of 139.14 m (456.5 ft) until April of each year. However, water depth alone does not control turbidity. In fact, WSEs were below 139.14 m (456.5 ft) by as much as 0.396 m (1.3 ft) in 2011 and 0.152 m (0.5 ft) in 2012 (fig. 2*B*). In addition, SAV was observed in 2011 only in protected areas where the shallow water was clear. Thus, we suggest that wind exposure is also a significant influence to turbidity at Topock Marsh.

Water depths continued to stay well below the 139.14 m (456.5 ft) WSE through 2013 and most of April 2014. Once the water elevation was raised to 139.14 m (456.5 ft) on April 28, 2014, it was kept at that approximate depth through May 26, 2014, to provide nesting habitat for Southwestern willow flycatchers (McLeod and Pellegrini, 2013). Subsequently, water levels were slowly lowered to the eventual winter low of 138.34 m (453.87 ft) (fig.2*B*). Turbidity measurements during the time of higher water depths, which were lower than those in 2011, improved the light penetration into the marsh and allowed more SAV coverage during the fall (tables 8 and 9). This was most likely because the deeper water prevented high winds from stirring up loose sediments from the marsh bottom and dispersing them into the water column.

Considering the critical role light plays on submerged plants (Cronk and Fennessy, 2001), turbidity was measured at the same locations as SAV coverage in 2012, 2013, and 2014. Because of the high turbidity observed in March 2012, it was expected that SAV growth would be sparse the following summer and large areas throughout the marsh would be unvegetated. However, higher water elevations later in 2012, and again in 2013 and 2014, may have caused turbidity levels in 2013–14 to be lower than in 2011 and early 2012, and better water clarity and ample light penetration encouraged abundant SAV growth (Sand-Jensen and Borum, 1991; Cronk and Fennessy, 2001). If water quality conditions and water depths in the future remain similar to conditions in 2013–14, it is likely the SAV will continue to proliferate in areas conducive for its growth. With that said, even with higher water elevations, we have shown that dense phytoplankton can cause water clarity problems. The highest algal biovolumes occurred at times when waterflow was either very low or predominantly stagnant. Because no outflow occurred throughout the duration of this 4-year study, nutrients, solutes, phytoplankton, zooplankton, and even macroinvertebrates continued to accumulate and concentrate at TP-8 as water evaporated in what was essentially a large evaporation pond in the downstream end of the marsh. To lower the incidence of phytoplankton blooms, a water management scenario that includes regular water flushing or flow-through may be key.

This study attempted to quantitatively measure actual SAV coverage across the 1,637-hectare (4,045-acre) wetland. After training the CSU land cover model to predict the various plant species, the model predicted the total area covered by SAV to be 1.536 km^2 (379.6 acres) in 2014 (Young and others, 2015). However, based on the hundreds of bathymetric points collected by the USGS team and the recording of the aquatic vegetation species and their abundance throughout the marsh, we believe this is an overestimate of the actual coverage by as much as two times. There were many locations along the October 2014 plant survey transects where SAV was not seen, yet the model predicted it to be there. Even so, the model was able to accurately predict areas where dense SAV grew in October 2014, as well as areas where dense SAV did not grow. The dead, standing mesquite trees that cover large swaths of the marsh and the across-the-board association of predicted SAV with edges of emergent vegetation may have contributed to the overestimation of the SAV. By collecting SAV coverage data along transects during different seasons, it became clear that dense SAV coverage and biomass occur during the fall each year. Although we attempted to quantify the area covered by species using the CSU land cover model (Young and others, 2015), the technology is not yet able to do it accurately. Hopefully, as the technology and imagery through turbid waters improve, SAV will eventually be accurately mapped.

In addition, the CSU land cover model did not accurately predict the correct emergent vegetation species. Even so, based on the hundreds of bathymetric points collected by the USGS team and the recording of the emergent vegetation species and their abundance throughout the marsh, it was determined that the model fairly accurately predicted the total of all emergent species as 10.662 km^2 (2,634.6 acres) (Young and others, 2015). Thus, the model's prediction of area covered by the combination of California bulrush and cattail, plus several minor emergent species, was fairly accurate.

As noted in the Emergent Aquatic Vegetation section under Results, Biological Characteristics, Aquatic Vegetation, it was observed during the low water, high summer temperature conditions of 2011 that cattail plants turned brown in many areas as their roots and rhizomes were exposed 30 cm (12 in.) or more above the waterline and California bulrush grew further out into deeper water. Both these plants are obligate wetland species and, so, are adapted to withstand variable wetland conditions (Cronk and Fennessy, 2001). As water levels resumed to more normal conditions, cattails recovered and thrived and the already established California bulrush continued to thrive in deeper water through the study period. Thus, the low water conditions that occurred between 2011 and early 2012 did not appear to harm the emergent plants.

Phytoplankton, Zooplankton, and Aquatic Macroinvertebrates

The results of the study show that Topock Marsh supported rich phytoplankton, zooplankton, and aquatic macroinvertebrate communities throughout 2011–14. In addition, their numbers and growth cycles showed spatial, as well as seasonal, variations.

During the low water conditions of 2011, phytoplankton species richness reached 193 individual taxa (table 10), but cell densities were relatively low except for a small blue-green algae bloom in October at TP-8 (fig. 23*A*). However, even though phytoplankton cell numbers remained low, the biovolume of diatom cells was high in February and March 2012 at TP-6. During that time, turbidity had also increased. Rather than assuming the turbidity was governed strictly by suspended sediments noted at that time, it appears that the diatom bloom also contributed to turbidity.

Total density and biovolumes of phytoplankton were much higher at TP-8, the most downstream sampling station, than at the upstream sampling stations in June, July, and October 2014 (fig. 23). As discussed in the Physicochemistry section under Results, Water Quality Characteristics, waterflow moved southward as evidenced by the higher SC moving downstream with higher waterflows, and solutes and nutrients concentrated at the downstream end of the marsh (tables 4 and 5, fig. 16). Thus, those higher nutrients became available to support additional phytoplankton growth (Vymazal, 1995) at TP-8, particularly during warmer temperatures.

We noted that peak air and water temperatures occurred between June and July 2013 (figs. 3*A* and 4*B*). The water temperature stratification observed in July 2013 at TP-8 (fig. 4*Bd*) corresponded to the highest levels of cell density and biovolume of phytoplankton collected during this study (fig. 23). These observations suggest that the combination of the warmer temperatures and higher nutrient concentrations triggered greater phytoplankton growth (Vymazal, 1995). Meanwhile, the relatively higher pH (fig. 8*Bd*) and DO (fig. 10*Bd*) values within the stratified layer suggest greater photosynthesis occurring with the larger biovolume (Cronk and Fennessy, 2001). TP-8 contained the highest chlorophyll *a* concentrations (fig. 15) and greatest phytoplankton biovolumes (fig. 23*B*) in 2013 and 2014, with little evidence of inorganic particles in the water column. Therefore, we conclude that phytoplankton was primarily responsible for higher turbidities at TP-8 in 2013 and 2014 (fig. 13*Bd*).

Most noteworthy among the 240 phytoplankton taxa collected in Topock Marsh during the 4-year sampling period were the blue-green algae, because many produce toxins that are dangerous to birds, wildlife, and humans (U.S. Geological Survey, 1999; Lopez and others, 2008). As suggested in ADEQ (2009), the maximum threshold criterion in warm water lakes designated for aquatic and wildlife use is 50 percent of the number of blue-green algal cells divided by the total phytoplankton cell count. This threshold was exceeded in October 2011 when blue-green algae made up 55 percent and 75 percent of the phytoplankton cell densities at TP-2 and TP-8, respectively, and in July 2013 when blue-green algae made up 66 percent and 77 percent of the phytoplankton cell densities at TP-6 and TP-8, respectively (fig. 23*A*). Even so, the species of blue-green algae known to produce virulent toxins (that is, *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*) (Vymazal, 1995) made up only 24 percent of all blue-greens at TP-8 in October 2011, and 36 percent and 14 percent of all blue-greens in July 2013 at TP-6 and TP-8, respectively. In addition, although blue-green algae was common throughout Topock Marsh during 2013–14, total numbers were not typically in the hazardous category (World Health Organization, 2003; John Beaver, oral commun., 2012) and, therefore, were not considered a significant threat to the wildlife using the area.

As with phytoplankton and water quality, seasonality also played a large role in influencing density and biomass of zooplankton in Topock Marsh. During the low water sampling period (2011–12), the highest density and biomass occurred in February 2012 at TP-8 (fig. 24). Rotifers had the highest densities in February and March 2012, but cladocerans made up the bulk of the biomass throughout the study period.

Likewise, during the high water sampling period (2013–14), the greatest zooplankton bloom was observed in February 2014 throughout most of the marsh. The second largest bloom occurred in April 2014 (fig. 24). Rotifers again had the highest densities during those sampling events (fig. 24*A*) and cladocerans made up the majority of the biomass (fig. 24*B*). TP-6 contained the largest density and biomass of zooplankton during the February 2014 bloom; however, by April 2014, total biomass was highest at TP-8. In fact, zooplankton biomass at TP-8 was 7.7 times higher than all upstream stations in April 2014. Density and biomass of zooplankton were substantially lower in July through October during all of the study years, compared to February and April of all years, which suggest that a strong seasonal influence was most likely due to temperature.

Species richness for aquatic macroinvertebrates collected in Topock Marsh during the 4-year sampling period was 78 taxa, and the mean number of organisms obtained varied depending on sampling time and site (table 12). Overall, TP-8 had the largest number of macroinvertebrates collected with a mean = 321 of total number of organisms collected during 10 sampling dates, followed by TP-2, TP-6, and TP-3. Both the average number of total taxa and total number of organisms increased appreciably from the 2011–12 sampling period to the 2013–14 sampling period; however, in 2013–14, more sampling trips were made (spring through fall) so it would be expected that a higher number and a wider diversity of macroinvertebrates would be collected.

Once quagga mussels were discovered in the marsh, we expected an increase in numbers of both the veliger and adults through time. However, only 12 adults and 20 veligers were collected in 2013, and 9 adults and 1 veliger were collected in 2014. No live adults were collected from the macroinvertebrate sampling in April or October 2014, and no other quagga mussels were seen elsewhere in the marsh. If monitoring for quagga mussels continues, FWS will be able to track any changes in the quagga population in the marsh should they occur. Caution is warranted, as literature suggests that the Havasu NWR's situation of having low-velocity water conveyance systems (that is, flow velocities less than 1.219 m/s [4 ft/s]) in a nutrient rich aqueous environment might be the ideal scenario for quagga mussel colonization (Benson and others, 2016).

Fish

The annual AGFD gill net data (table 13 and figs. 25*A* and *B*), plankton data (figs. 23 and 24), aquatic macroinvertebrate data (table 12), and water-quality data discussed in this report, suggest that Topock Marsh was suitable habitat for fish both before and after switching inflow from the Inlet Canal to the Fire Break Canal (fig. 1). However, if gizzard shad are excluded from the total number of fish captured per net in each region, the data show that most species of fish declined from 2010 to 2015. Therefore, perhaps more relevant to the fish population in the marsh is the correlation between the decline in numbers of most fish species when gizzard shad significantly increased in numbers (fig. 26). A decline in fish numbers after the appearance of gizzard shad in the lower Colorado River basin has previously been reported (Cantrell, 2013), and gizzard shad are considered a potential threat to native and recreational fisheries because of competition and predation (Mueller and Brooks, 2004). We cannot say unequivocally that the recent appearance of gizzard shad was due to infrastructure modifications, but that seems likely because the discovery of the gizzard shad was made following the completion of the new Fire Break Canal. In addition, it is known that this species has been proliferating in this region of the Colorado River for nearly a decade (Finney and Fuller, 2008; Loomis and others, 2011).

The inability to find razorback suckers in 2015 may not mean they are completely gone. Ten gill nets set during a one-week period in February may miss representatives of this relatively small population of razorback suckers in a given year. However, it is troubling that their numbers were declining in 2013–14 and none were found in 2015. Continued yearly surveys should give biologists a better idea about the status of the razorback sucker population in Topock Marsh.

Management Relevancy

Based on the water-quality and aquatic-biota data that are summarized in this report, we can expect certain water management scenarios to potentially affect various parameters within Topock Marsh. The ideas expressed here are not suggestions, but instead can be used as information for the FWS, specifically water management staff at Havasu NWR, to better prepare for their future water management needs.

If low inflows and no outflow occur for any length of time in Topock Marsh, SC will increase throughout Topock Marsh, but particularly at the southern end of the marsh, as a result of the evaporation and concentration of solutes. Phytoplankton blooms will likely continue, causing increased turbidity and (or) increased toxic blue-green algae production. Lower water elevations will eventually occur under this scenario, which will encourage more emergent plant growth into currently open water areas and possibly less submerged vegetation growth because of potentially more turbid conditions. Although we found no evidence that there was less fish production because of shallower, more turbid, and warmer conditions, those conditions possibly could restrict quagga mussel and (or) Eurasian watermilfoil proliferation.

Once the planned infrastructure upgrades are completed, the low flow conditions of 2011–12 are less likely to reoccur. Adequate inflow from the Colorado River, potentially supplemented with pumped groundwater, and outflow through the South Dike will reduce the potential for evaporation-induced SC increases, concentration of nutrients, and subsequent phytoplankton blooms causing additional turbidity, as well as the potential for other stagnant water issues not addressed here (such as avian botulism, avian cholera, and so on) (U.S. Geological Survey, 1999). Greater water depths maintained at least through the end of June each year, will provide proper soil moisture for Southwestern willow flycatcher habitat (McLeod and Pellegrini, 2013) and control emergent vegetation proliferation but encourage SAV growth. Greater water depths could also reduce water temperatures during the summer, which would benefit fish (Beitinger and others, 2000), including gizzard shad.

The Havasu NWR's current practice of maintaining shallower water depths from late October through mid-December to provide better access to SAV for migrating and overwintering waterfowl is still a viable management practice. We suggest that additional adaptive management scenarios incorporating the many conflicting habitat needs can best be determined using a DSS tool developed for the Havasu NWR. Phase 1 of the Havasu NWR DSS, developed by USGS (Holmquist-Johnson and others, 2016), is a hindcasting model that can be used by the refuge managers to determine the total volume of water that must be added or subtracted throughout the year to meet a prescribed range of marsh elevations. Refuge managers, along with Reclamation engineers, can then determine the availability of Colorado River water and the most efficient method of delivering that specific volume of needed water to the marsh.

Phase 2 of the Havasu NWR DSS, if funded, would build on the current Phase 1 hindcasting model DSS and would incorporate output from water management operations and hydrodynamic (that is, water quantity and quality) modeling based on marsh bathymetry, Colorado River hydrology, and future water delivery methods used by the Havasu NWR. Synthesis of these additional model outputs could allow FWS to compare different hydrologic scenarios and water management operations and delivery methods to determine their effects on species-specific habitat. Once these tools are developed, they could be valuable for, and directly applicable to, future analysis needs such as in-depth evaluation of climate change impacts. The Phase 2 DSS could be a powerful illustration of water management for optimized biological outcomes that could be applied to other locations beyond the Havasu NWR, thus providing resource managers the best available science to determine the most effective water management strategies.

Conclusions

At the request of the U.S. Fish and Wildlife Service Region 2 office, U.S. Geological Survey biologists conducted water quality and aquatic biota sampling from July 2011 to March 2012 to evaluate conditions at Topock Marsh, Arizona, during unusually low water elevations. Subsequently, sampling was resumed during 2013–14 to assess the same parameters under more normal water elevations (that is, higher inflows but no outflow). In total, the marsh was sampled 11 times at 4 sampling stations, denoted as TP-3, TP-2, TP-6, and TP-8, which were located north to south, from upstream to downstream, and parallel to the Colorado River. The most noteworthy findings are summarized here.

1. Turbidity levels in 2011 through early 2012 were high as prevailing winds stirred up loose sediments in the shallower water. Turbidity was generally lower in 2013–14 because water elevations were higher, with the exception of higher turbidities at the marsh terminus (measured at TP-8) because of high densities and biovolume of phytoplankton.
2. High turbidity levels decrease light penetration, which most likely discouraged submerged aquatic vegetation (SAV) growth in the more exposed areas of the marsh or under dense phytoplankton.
3. Spiny naiad (*Najas marina*) was the dominant SAV throughout Topock Marsh and was most abundant in shallow (0.60–0.76 meters [2.0–2.5 feet] depth) protected areas where water clarity was relatively high. Sago pondweed (*Stuckenia pectinata*) occurred in low to moderate amounts in clear, typically shallower areas (0.30–0.46 meters [1.0–1.5 feet] depth). Virtually no rooted SAV was observed from January to March every year of the study, and all SAV species were most abundant in October of every year studied.
4. The unusually shallow water in 2011, which was approximately 29.2 centimeters (0.96 feet) below average growing season levels, permitted existing stands of emergent plant species to expand laterally into water that was previously too deep. Simultaneously, cattail (*Typha* sp.) and California bulrush (*Schoenoplectus californicus*) roots and rhizomes growing at higher elevations were exposed to desiccating conditions under the high air temperatures. Even after surviving these stressful conditions, both cattail and California bulrush recovered in the following years and continued to thrive.
5. Three new nonnative aquatic species were discovered in 2012 following completion of the new Fire Break Canal: gizzard shad (*Dorosoma cepedianum*), quagga mussel (*Dreissena bugensis*) (both adult and veliger stages), and Eurasian watermilfoil (*Myriophyllum spicatum*). In 2012, a floating sprig of Eurasian watermilfoil was found but no rooted plants were reported. Gizzard shad and Eurasian watermilfoil increased in abundance through the study period, but the abundance of quagga mussels did not increase.
6. Quagga mussels and toxin-producing blue-green algae (Cyanobacteria) were found in low densities throughout the 2011–14 study period. We suspect that high turbidity levels and warm water temperatures may have slowed quagga mussel proliferation. Densities of blue-green algae measured from 2011 to 2014 did not typically reach levels in the hazardous category, but the potential for hazardous blooms is possible under warm water temperatures and no-to low-flow conditions.
7. Fish abundance exhibited no measurable signs of impact from water elevation or water quality changes throughout the study period. Although species richness of phytoplankton, zooplankton, and aquatic macroinvertebrates indicated that adequate food was available for fish as well as other wildlife, some fish species in Topock Marsh may have been negatively impacted by the sudden increase in gizzard shad. The population of the endangered razorback sucker (*Xyrauchen texanus*), which was reintroduced in 2010, appeared to be thriving and in good condition, with numbers captured in gill net surveys peaking in 2012. However, their numbers declined in 2013 and 2014, and none were captured in 2015.
8. Following the 260-day period of no flow through the Inlet Canal in 2011, Colorado River water flowing into the marsh through the new Fire Break Canal lowered specific conductance (SC), total dissolved solids, turbidity, chlorophyll *a*, total and organic nitrogen, and phytoplankton concentrations at the upstream sampling stations, and pushed water with higher concentrations downstream. Comparing these SC concentrations with historical data reveal that average SC values in the marsh from when the Fire Break Canal became operational

(January 2012) to January 2015 are only slightly higher (1.12 times) than values reported in another study for 1995–1998. Those time periods did not experience the previous extremes (highs and lows) that occurred between late 1987 and May 1994 and between late 2003 and January 2011 when fairly consistent trends of SC concentrations peaking during the winter prior to spring water releases from Davis Dam were apparent.

9. Concentrations of nutrients and trace elements (including arsenic, mercury, selenium, and hexavalent chromium) in water, sediment (with one slightly elevated exception for arsenic), and plant samples were below toxicity thresholds throughout the sampling period.

10. Further monitoring and statistical analysis are necessary to evaluate the long-term effects of the nonnative biota (that is, quagga mussels, gizzard shad, and Eurasian watermilfoil), as well as subsequent changes in water management, on the native aquatic flora, fauna, and water quality of Topock Marsh.

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Appendix 1. Long-Term Water Chemistry Data for Topock Marsh From Late 1983 to Early 2015

The Excel spreadsheet Appendix-1.xls provides long-term chemistry data for Topock Marsh, Arizona from November 1983 to April 2015.

Appendix 2. Topock Marsh General Fish Surveys and Reports

- Topock Marsh General Fish Surveys 2010 and 2011—Excel tables by Gregg Cummins and Matt Chmiel, Arizona Game and Fish Department (AGFD), February 2010 and February 2011, 2 tables in spreadsheet.
- Topock Marsh General Fish Survey 2012 by Gregg Cummins, David Partridge, and Matt Chmiel, AGFD, February 2012, 2 pg.
- Topock Marsh General Fish Survey 2013 by Gregg Cummins and David Partridge, AGFD, February 2013, 2 pg.
- Topock Marsh Fish Survey Report—February 2014 by Gregg Cummins, AGFD, April 2014, 6 pg.
- Topock Marsh Fish Survey Report—February 2015 by Gregg Cummins, AGFD, March 2015, 8 pgs.

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