

APPENDIX **A**

Light Requirements for
Chesapeake Bay and
Other SAV Species

TABLE A-1. Summary of light saturation (I_k) and light compensation point (I_c) for freshwater-oligohaline SAV species.

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{s}^{-1}$)	K_m ($\mu\text{mol m}^2 \text{s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Hydrilla verticillata</i> (¹ dioecious)		600	80	15	Florida	Laboratory	30	AS	Van <i>et al.</i> 1976
<i>H. verticillata</i> (¹ monoecious, dioecious)		300-400	40	10	Florida	Laboratory	24 ±2	AS	Steward 1991b
<i>H. verticillata</i> (¹ dioecious)	Growth light varied	150-600 -----	27-105 -----	7-20 -----	Florida	Laboratory ----- grown at 6 μmol 30 μmol 120 μmol 300 μmol	25	AS	Bowes <i>et al.</i> 1977a
<i>Myriophyllum spicatum</i>	Temperature and season varied	341 ± 134 (mean)		84 ±35 (mean)	Hudson River	River (14% surface light)	AM	AS	Harley and Findlay 1994
<i>M. spicatum</i>		600	120	35	Florida	Laboratory	30	AS	Van <i>et al.</i> 1976
<i>M. spicatum</i>			90	38	Lake George, New York	Laboratory	20	AS	Madsen <i>et al.</i> 1991
<i>M. spicatum</i>		200			Ontario	Laboratory	25	UL	Lloyd <i>et al.</i> 1977

Temp = temperature; AL = apical leaves; AS = apical section; WP = whole plants; UL = underwater leaves; AM = ambient; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

¹Monoecious = with stamens and pistils in separate flowers on the same plant; dioecious = unisexual, with the two kinds of flowers on separate plants.

continued

TABLE A-1. Summary of light saturation (I_k) and light compensation point (I_c) for freshwater-oligohaline SAV species (*continued*).

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{s}^{-1}$)	K_m ($\mu\text{mol m}^2 \text{s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>M. spicatum</i>	Growth light varied		164/ 365*		Wisconsin (shade plant/sun plant*)	Laboratory	25	WP AS	Titus and Adams 1979
<i>Elodea canadensis</i>			22	12	Lake George, New York	Laboratory	20	AS	Madsen <i>et al.</i> 1991
<i>Vallisneria americana</i>	Temperature and season varied	179±77 (mean)		30±36 (mean)	Hudson River	River (7% surface light)	AM	AS	Harley and Findlay 1994
<i>V. americana</i>	Growth light varied		22	10	Lake George, New York	Laboratory	20	AS	Madsen <i>et al.</i> 1991
<i>V. americana</i>		140 (whole plant, day 1)	60/197*		Wisconsin (shade plant/sun plant)*	Laboratory	25	WP AL	Titus and Adams 1979
<i>Ceratophyllum demersum</i>		700	145	35	Florida	Laboratory	30	AS	Van <i>et al.</i> 1976
<i>C. demersum</i>	Temperature and season varied	50-350 mean= 138			England	Pond	4-15	AS	Fair and Meeke 1983
<i>C. demersum</i>			23-360		Wisconsin				Titus 1977
<i>C. demersum</i>		210		5-10	Netherlands	Laboratory	20	AS	Best 1986

Temp = temperature; AL = apical leaves; AS = apical section; WP = whole plants; UL = underwater leaves; AM = ambient; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

¹Monoecious = with stamens and pistils in separate flowers on the same plant; dioecious = unisexual, with the two kinds of flowers on separate plants.

continued

TABLE A-1. Summary of light saturation (I_k) and light compensation point (I_c) for freshwater-oligohaline SAV species (*continued*).

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{s}^{-1}$)	K_m ($\mu\text{mol m}^2 \text{s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Potamogeton</i> spp			20-40	10-25	Lake George, New York	Laboratory	20	AL or AS	Madsen <i>et al.</i> 1991
<i>Potamogeton crispus</i>	Growth light varied	450	207, 245		Italy	Laboratory	25	AS	Baudo 1981
<i>P. crispus</i>		45:130 with epiphytes		22-37 for plant plus epiphytes	Denmark	Laboratory	15-20	AS	San-Jensen and Revsbech 1987
<i>Potamogeton perfoliatus</i>	Temperature and season varied	387±123 (mean)		52±22 (mean)	Hudson R. (15% surface light)	River	AM	AS	Harley and Findlay 1994
<i>P. perfoliatus</i>				25-60	Chesapeake Bay	Incubator	AM	AS	Goldsborough and Kemp 1988
<i>P. perfoliatus</i>	Growth light varied	450	95, 292		Italy	Laboratory	25	AS	Baudo 1981
<i>Potamogeton pectinatus</i>	Temperature varied		173 312*		New York	Laboratory	30 10*	AS	Madsen and Adams 1989
<i>Hippuris vulgaris</i> , <i>E. canadensis</i> , <i>P. perfoliatus</i> , <i>P. crispus</i> , <i>P. spp.</i>			102-114	5-15	United Kingdom	Laboratory	20	AS	Maberly 1983
<i>Potamogeton amphifolius</i>		200			Ontario	Laboratory	25	UL	Lloyd <i>et al.</i> 1977
<i>Cabomba caroliniana</i>		700	160	55	Florida	Laboratory	30	AS	Van <i>et al.</i> 1976

Temp = temperature; AL = apical leaves; AS = apical section; WP = whole plants; UL = underwater leaves; AM = ambient; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

*Monoecious = with stamens and pistils in separate flowers on the same plant; dioecious = unisexual, with the two kinds of flowers on separate plants.

continued

TABLE A-1. Summary of light saturation (I_k) and light compensation point (I_c) for freshwater-oligohaline SAV species (*continued*).

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{s}^{-1}$)	K_m ($\mu\text{mol m}^2 \text{s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Najas marina</i>		280		5	Yarkon River, Israel	River	20	WP	Agami <i>et al.</i> 1980
<i>Myriophyllum brasiliense</i>		250-300		42-45	Florida	Laboratory	30	AS	Salvucci and Bowes 1982
<i>Myriophyllum salsugineum</i>	Temperature and P measurement varied	41.5-174		2.4-16.9	Australia	Laboratory	15-35	AS	Orr 1988
		93		1.4-1.8			25		

Temp = temperature; AL = apical leaves; AS = apical section; WP = whole plants; UL = underwater leaves; AM = ambient; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

¹Monoecious = with stamens and pistils in separate flowers on the same plant; dioecious = unisexual, with the two kinds of flowers on separate plants.

TABLE A-2. Summary of light saturation (I_k) and light compensation point (I_c) for mesohaline-polyhaline SAV species.

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{ s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{ s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Zostera marina</i>		100	10	Woods Hole	Field	21-23	LS	Dennison and Alberte 1982
<i>Z. marina</i>	Epiphytes varied	40-125	7-33	Woods Hole	Laboratory	20-25	LS	Mazzella <i>et al.</i> 1980
<i>Z. marina</i>		65-120	15-25	Woods Hole	Laboratory	20	LS	Dennison and Alberte 1985
<i>Z. marina</i>	Temperature varied	7 to 120	0.9 to 35	Woods Hole	Laboratory	0-35	LS	Marsh <i>et al.</i> 1986
<i>Z. marina</i>	Temperature varied/ plus epiphytes	600-700		North Carolina	<i>in situ</i> chambers	15, 22, 29	WP	Penhale 1977
<i>Z. marina</i>	Temperature and season varied	$K_m = 300$ (12.5 % surface)		Alaska	Lagoon	AM	PR	McRoy 1974
<i>Z. marina</i>		485 380 230		Denmark	Laboratory lvs w/ep; lvs w/o ep; ep	10	LS	Sand-Jensen 1977
<i>Z. marina</i>		300 est. from $K_d/150$ from PI curves		Long Island Sound	Field Laboratory		WP LS	Koch and Beer 1996
<i>Z. marina</i>	Temperature varied	28-46 mean = 37		Chesapeake Bay	Laboratory	Various	LT	Evans <i>et al.</i> 1986
<i>Z. marina</i>		35 ± 17		San Francisco Bay	Laboratory	15	LS	Zimmerman <i>et al.</i> 1991
<i>Z. marina</i>	Temperature varied seasonally	80-385; mean= 238 ± 117	25-417	Chesapeake Bay	<i>in situ</i> dome incubations	1-28 for I_k ; 6-28 for I_c	WP	Wetzel and Penhale 1983
<i>Z. marina</i>		208	25	Great Britain	Laboratory	15	LS	Drew 1979

Temp = temperature; AM = ambient; lvs = leaves; LS = leaf sections; LT = leaf tips; WP = whole plants; ep = epiphytes; ES = entire shoot; PR plant with roots; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

continued

TABLE A-2. Summary of light saturation (I_k) and light compensation point (I_c) for mesohaline-polyhaline SAV species (*continued*).

Species	Experimental design	I_k ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	I_c ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Phyllospadix torreyi</i>		150	21	Great Britain	Laboratory	15	LS	Drew 1979
<i>Cymodocea nodosa</i>		158	17	Great Britain	Laboratory	25	LS	Drew 1979
<i>Zostera angustifolia</i>		133	12	Great Britain	Laboratory	10	LS	Drew 1979
<i>Halophila stipulacea</i>		83	8	Great Britain	Laboratory	25	lvs	Drew 1979
<i>Posidonia oceanica</i>		108	7	Great Britain	Laboratory	17	LS	Drew 1979
<i>Thalassia testudinum</i> <i>Halodula wrightii</i> <i>Syringodium filiforme</i>			15/33/14 corrected for respiration 40/65/35	Florida Bay	Laboratory	25-30	shoots	Fourqurean and Zieman 1991a
<i>Thalassia testudinum</i>	Tested PI models	357-438		plants from Florida Bay	Laboratory	25-30	shoots	Fourqurean and Zieman 1991b
<i>T. testudinum</i>	Compared sensors, whole plants vs. leaves	290 85	112 30	Texas	<i>in situ</i> Laboratory	AM	WP lvs	Herzka and Dunton 1997
<i>H. wrightii</i>	Seasonal	127-365 mean = 308	28-235 mean = 73	Laguna Madre, Texas	<i>in situ</i>	AM	WP	Dunton and Tomasko 1991
<i>H. wrightii</i>	Compared lab and field/seasonal	Field: 189-453 seasonal mean = 319; Mean at 29 °C = 349±27/ Lab: 101±4	Field: 37-177 seasonal mean = 85; Mean at 29 °C = 111±21/ Lab: 22±2	Laguna Madre, Texas	Field (<i>in situ</i>) Laboratory	12-30 Field/ 29 Lab	Field: WP/ Lab: LS	Dunton and Tomasko 1994

Temp = temperature; AM = ambient; lvs = leaves; LS = leaf sections; LT = leaf tips; WP = whole plants; ep = epiphytes; ES = entire shoot; PR plant with roots; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

continued

TABLE A-2. Summary of light saturation (I_k) and light compensation point (I_c) for mesohaline-polyhaline SAV species.

Species	Experimental design	I_k ($\mu\text{mol m}^2 \text{s}^{-1}$)	I_c ($\mu\text{mol m}^2 \text{s}^{-1}$)	Location	Venue	Temp °C	Plant part	Reference
<i>Ruppia maritima</i>	Temperature varied	45-72 mean = 57		Chesapeake Bay	Laboratory	Various	LT	Evans <i>et al.</i> 1986
<i>R. maritima</i>		396-1200	11-88	Plants from North Carolina and Florida	Laboratory	14,22,30	LS	Koch and Dawes 1991
<i>R. maritima</i>	Temperature varied seasonally	150-561	133-311	Chesapeake Bay	<i>in situ</i> dome incubations	1-28 for I_k ; 6-28 for I_c	WP	Wetzel and Penhale 1983
<i>Cymodocea nodosa</i> ; <i>Posidonia oceanica</i>	Temperature varied	83-125		Malta	Laboratory and <i>in situ</i>	14.5-25	LS	Drew 1978

Temp = temperature; AM = ambient; lvs = leaves; LS = leaf sections; LT = leaf tips; WP = whole plants; ep = epiphytes; ES = entire shoot; PR plant with roots; I_k = irradiance at saturation; I_c = compensation point; K_m = 1/2 saturation constant or 1/2 P_{max} .

TABLE A-3. Summary of Chesapeake Bay SAV species light limitation studies involving measurements or estimates of percent of surface light at maximum depth (Z_{\max}) from field observations.

Species	Light Measurements	Maximum Depth of Growth (Z_{\max}) (m)	Light at Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>Hydrilla verticillata</i>	PAR-photometer		5 ($<100 \mu\text{mol m}^{-2} \text{s}^{-1}$)	Florida (outside aquarium)	Ambient	Steward 1991b
<i>H. verticillata</i>	Intermittent PAR measurements-photometer	4.6-1.8	~5	Lake Tutira, New Zealand	Ambient	Johnstone and Robinson 1987
<i>H. verticillata</i>	Secchi depth and PAR (10 lakes)/ regression used to estimate 16 other lakes		0.46-5.4	Florida lakes	Ambient	Canfield <i>et al.</i> 1985
<i>Elodea canadensis</i>	Clear midsummer day-photometer	12	10	Lake George, New York	>20	Sheldon and Boylen 1977
<i>E. canadensis</i>	Intermittent PAR measurements-photometer	1.8- 6.7	<5	Lake Tutira, New Zealand	Ambient	Johnstone and Robinson 1987
<i>E. canadensis</i>	Photometer (early model)		<2	Lake Erie	23-26	Meyer <i>et al.</i> 1943
<i>E. canadensis</i>	Semi-monthly or monthly PAR measurements	12-14	0.5-1	Shoal Lake, Manitoba, Ontario	18.7 in Aug.	Pip and Simmons 1986
<i>E. canadensis</i>	Optical measurements	4.5	4.5	Trout Lake, Wisconsin		Hutchinson 1975
<i>Vallisneria americana</i>	Optical measurements	4.5	4.5	Trout Lake, Wisconsin		Hutchinson 1975
<i>V. americana</i>	Clear midsummer day-photometer	7	~20	Lake George, New York	>20	Sheldon and Boylen 1977

continued

TABLE A-3. Summary of Chesapeake Bay SAV species light limitation studies involving measurements or estimates of percent of surface light at maximum depth (Z_{\max}) from field observations (*continued*).

Species	Light Measurements	Maximum Depth of Growth (Z_{\max}) (m)	Light at Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>V. americana</i>	Photometer (early model)		<2	Lake Erie	23-26	Meyer <i>et al.</i> 1943
<i>V. americana</i>		1.34	2.4-3.7 (30.5 - 37.9 $\mu\text{mol m}^{-2} \text{s}^{-1}$)	Wisconsin Lake/Laboratory	Ambient	McAllister 1991
<i>V. americana</i>	Photometer– tubers planted different depths	0.5 1.0 1.5	9 depth new tubers formed	Lake Onalaska, Wisconsin	Ambient	Kimber <i>et al.</i> 1995
<i>Potamogeton pectinatus</i>	Not documented	3.1	5	Swartvlei system (estuary-lake complex) in South Africa–brackish	Ambient	Howard-Williams and Liptrot 1980
<i>P. pectinatus</i>	Optical measurements	2.5	14	Trout Lake, WI		Hutchinson 1975
<i>P. pectinatus</i>	Clear midsummer day–photometer	3	~52	Lake George, New York	>20	Sheldon and Boylen 1977
<i>Potamogeton crispus</i>	Clear midsummer day–photometer	3	~52	Lake George, New York	>20	Sheldon and Boylen 1977
<i>Heteranthera dubia</i>	Photometer (early model)		<2	Lake Erie	23-26	Meyer <i>et al.</i> 1943
<i>Potamogeton perfoliatus</i>	Secchi depth		4	England		Pearsall 1920
<i>P. perfoliatus</i>	Clear midsummer day–once–photometer	7	20	Lake George, New York	>20	Sheldon and Boylen 1977
<i>Najas flexilis</i>	Clear midsummer day–once–photometer	9	17	Lake George, New York	>20	Sheldon and Boylen 1977
<i>N. flexilis</i>	Photometer (early model)		2-3	Lake Erie	23-26	Meyer <i>et al.</i> 1943

continued

TABLE A-3. Summary of Chesapeake Bay SAV species light limitation studies involving measurements or estimates of percent of surface light at maximum depth (Z_{max}) from field observations (*continued*).

Species	Light Measurements	Maximum Depth of Growth (Z_{max}) (m)	Light at Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>Naja flexilis</i>	Semi-monthly or monthly PAR measurements—photometer	12-14	0.5-1	Shoal Lake, Manitoba-Ontario	18.7 in Aug.	Pip and Simmons 1986
<i>N. flexilis</i>	Optical measurement	5.5	3.1	Trout Lake, WI		Hutchinson 1975
<i>Ceratophyllum demersum</i>	Optical measurement	6.5	1.8	Trout Lake, WI		Hutchinson 1975
<i>C. demersum</i>	Semi-monthly or monthly PAR measurements—photometer	12-14	0.5-1	Shoal Lake, Manitoba-Ontario	18.7 in Aug.	Pip and Simmons 1986
<i>C. demersum</i>	Secchi depth and PAR (10 lakes)/ regression used to estimate 16 lakes		1.1-3.4	Florida	Ambient	Canfield <i>et al.</i> 1985
<i>Heteranthera dubia</i>	Clear midsummer day—photometer	5	38	Lake George, NY	>20	Sheldon and Boylen 1977
<i>P. perfoliatus</i> <i>P. pectinatus</i> <i>V. americana</i>	Photometer (early model)	transplants—no survival	2-8 at 1 m	Back Bay, North Bay, Currituck Sound	Ambient	Bourn 1932
<i>Z. marina</i>	Secchi depth		almost same as Secchi depth, about 10%			Ostenfield 1908
<i>Z. marina</i>	Photometer weekly, Feb.-Dec.	0.5 1.0 1.5 2.0 2.0	21.2 11.1 5.8 4.1 5.0	San Francisco Bay	Ambient	Zimmerman <i>et al.</i> 1991

continued

TABLE A-3. Summary of Chesapeake Bay SAV species light limitation studies involving measurements or estimates of percent of surface light at maximum depth (Z_{max}) from field observations.

Species	Light Measurements	Maximum Depth of Growth (Z_{max}) (m)	Light at Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>Z. marina</i>	Photometer—average K_d over year	6	18.6	Woods Hole, MA	Ambient	Dennison 1987
<i>Z. marina</i>	Photometer monthly (May-October)	1 4	35.7 15	Long Island Sound, NY	Ambient	Koch and Beer 1996
<i>Z. marina</i>	Year-round measurements of light intensity—photometer	1.5	20 (summer/fall); 25-30 (winter/spring)	York River, VA	Ambient	Moore 1991

TABLE A-4. Summary of studies of SAV species light limitation involving measurements or estimates of percent of surface light at maximum depth (Z_{\max}) from field observations. Freshwater-polyhaline species not found in the Chesapeake Bay.

Species	Light Measurements	Maximum Depth of Growth Z_{\max} (m)	Light of Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>Elodea baldwinii</i>	Secchi depth measured once at peak abundance		4.8± 2.185	Florida	No data	Canfield <i>et al.</i> 1985
<i>Utricularia vulgaris</i>	Secchi depth measured once at peak abundance		6.2± 2.1	Florida	No data	Canfield <i>et al.</i> 1985
<i>Hippuris vulgaris</i>	PAR measured on sunny day in June	6	15 (100 $\mu\text{mol m}^{-2} \text{s}^{-1}$)	Scotland	15	Bodkin <i>et al.</i> 1980
<i>Potamogeton berchtoldii</i>			2-15	England		Hutchinson 1975
<i>Potamogeton praelongus</i>			2-10	England		Hutchinson 1975
<i>Potamogeton alpinus</i>			4-40	England		Hutchinson 1975
<i>Potamogeton</i> spp.	Optical measurements	0.5-6	2.4-62	Trout Lake, WI		Hutchinson 1975
<i>Myriophyllum</i> spp.		2.5-4	5.9-10	Trout Lake, WI		Hutchinson 1975
<i>Thalassia testudinum</i> <i>Halodule wrightii</i> <i>Syringodium filiforme</i>	Whole plant PI curves—calculated		10-20	Florida Bay	Ambient	Fourqurean and Zieman 1991b
<i>T. testudinum</i> ; <i>H. wrightii</i> ; <i>S. filiforme</i>	Light depth profiles for 20 months— photometer—PAR		15	Laguna Madre, TX	Ambient	Onuf 1991

TABLE A-4. Summary of studies of SAV species light limitation involving measurements or estimates of percent of surface light at maximum depth (Z_{\max}) from field observations. Freshwater-polyhaline species not found in the Chesapeake Bay (*continued*).

Species	Light Measurements	Maximum Depth of Growth Z_{\max} (m)	Light of Maximum Depth (% of surface irradiance)	Location	Temp °C	Reference
<i>H. wrightii</i> <i>S. filiforme</i>	Light profiles and depth distribution— photometer	2-2.75	24-37	Hobe Sound, Jupiter Sound, NC	Ambient	Kenworthy and Fonseca 1996
<i>H. wrightii</i> , <i>S. filiforme</i>	Light profiles and depth distribution— photometer		>10-15	Indian River Lagoon, FL	Ambient	Kenworthy <i>et al.</i> 1991