

Under Construction

The SOLEC indicator process is an open process, a process that also needs to be flexible enough to revise, remove or add indicators as conditions warrant. Additionally, the process needs to be able to correct oversights.

Since SOLEC 98 one frequent comment has been that the suite of indicators lacks a basinwide indicator to assess the status and potential impact of non-native species. In response to this, SOLEC organizers are proposing the addition of an Exotic Species indicator (ID# 9002). Although we do not know have an indicator descriptor for Exotic Species, an example indicator report for aquatic exotic species is included here. At some point the indicator report will expand to the terrestrial portion of the Great Lakes ecosystem.

Please provide comments to Paul Bertram or Nancy Stadler-Salt on:

1. Whether this indicator should be included in the SOLEC suite of basinwide ecosystem indicators;
2. What features need to be included in the indicator; and/or
3. Provide additional data for the indicator report.

Exotic Species Introduced into the Great Lakes

SOLEC Indicator #9002

Purpose

This indicator reports introductions of aquatic organisms not naturally occurring in the Great Lakes, and is used to assess the status of biotic communities in these freshwater ecosystems. Human activities associated with shipping, canals, deliberate release (authorized and not), and aquaculture are responsible for virtually all new species in the Great Lakes. Reporting new species will highlight the need for more effective safeguards to prevent the introduction and establishment of new non-indigenous species.

Ecosystem Objective

The purpose of the U.S. and Canada Water Quality Agreement is, in part, to restore and maintain the biological integrity of the waters of the Great Lakes ecosystem, that is, at a minimum to prevent extinctions and unauthorized introductions. Nearly 10% of the non-native species introduced in the Great Lakes have had a significant impact on ecosystem health, a percentage consistent with findings in the United Kingdom and the Hudson River of North America. In particular and most recently, live fish and invertebrates in ballast water discharges into the Great Lakes have been demonstrated to constitute a threat to the ecosystem.

State of the Ecosystem

Authorized and accidental introduction of new species by government agencies are managed through consultation and procedural agreements under *A Joint Strategic Plan for Management of Great Lakes, 1981*. Since this agreement, new sport fish related introductions have not become established in the Great Lakes.

The identification of ship ballast water as a major vector transporting unwanted organisms into the Great Lakes has motivated control efforts. In 1989, Canada introduced voluntary ballast exchange, as recommended by the International Joint Commission and Great Lakes Fishery Commission in the wake of Eurasian ruffe and zebra introductions. In 1990, the United States Congress passed the Aquatic Nuisance Control and Prevention Act (followed by the Non-Indigenous Species Act) and by May of 1993, the first and only ballast management regulations in the world was adopted. Since the mandatory ballast exchange policy in the Great Lakes was initiated, new species associated with shipping activities have been identified and non-reproducing indicator

species' such as the European Flounder are still reported. Consequently, current ballast water management strategies are not sufficiently protective against future Great Lakes invasions.

Future Pressures on the Ecosystem

World trends in global trade will increase the number of potential donor regions importing into the Great Lakes basin, thereby elevating the risk that new species will gain access to the Great Lakes. New diversions of water into the Great Lakes would also increase the risk of new invasive species. Fast-growing aquaculture industries, such as fish farming, live food, and garden ponds, will seek to satisfy their clients' desire for novelty. Changes in water quality, temperature, and, indeed, the previous introduction of key species from outside may make the Great Lakes more hospitable for the establishment of new invaders.

Future Actions

Researchers are seeking to better understand the contributions of various vectors and donor regions, the receptivity of the Great Lakes Ecosystem, and the biology of new invaders, in order to recommend improved safeguards that will reduce the invasion risk of new biological pollutants in the Great Lakes.

Further Work Necessary

To restore and maintain the biological integrity of the Great Lakes, it is essential that vectors be closely monitored and effective safeguards introduced and adjusted as necessary.

Acknowledgments

Authors: Edward L. Mills, Department of Natural Resources, Cornell University, Bridgeport, NY and Margaret Dochoda, Great Lakes Fishery Commission, Ann Arbor, MI.

Table 1. Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic fauna of the Great Lakes

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Fish						
Petromyzontidae	<i>Petromyzon marinus</i>	sea lamprey	Atlantic	1830s	Lake Ontario	C, S(F)
Clupeidae	<i>Alosa pseudoharengus</i>	alewife	Atlantic	1873	Lake Ontario	C, R(F)
	<i>Alosa aestivalis</i>	blueback herring	Atlantic	1978	Mohawk River	C
Cyprinidae	<i>Carassius auratus</i>	goldfish	Asia	<1878	widespread	R(D), R(AQ) R(F), R(A)
	<i>Cyprinus carpio</i>	common carp	Asia	1879	widespread	R(D)
	<i>Notropis buchanani</i>	ghost shiner	Mississippi	1979	Thames River	R(F)
	<i>Phenacobius mirabilis</i>	suckermouth minnow	Mississippi	1950	Ohio	C, R(F)
	<i>Scardinius erythrophthalmus</i>	rudd	Eurasia	1989	Lake Ontario	R(F)
Cobitidae	<i>Misgurnus anguillicaudatus</i>	oriental weatherfish	Asia	1939	Shiawassee River	R(A)
Ictaluridae	<i>Noturus insignis</i>	margined madtom	Atlantic	1928	Oswego River	C, R(F)
Osmeridae	<i>Osmerus mordax</i>	rainbow smelt	Atlantic	1912	Crystal Lake	R(D)
Salmonidae	<i>Oncorhynchus gorbuscha</i>	pink salmon	Pacific	1956	Current River	R(A)
	<i>Oncorhynchus kisutch</i>	coho salmon	Pacific	1933	Lake Erie	R(D)
	<i>Oncorhynchus nerka</i>	kokanee	Pacific	1950	Lake Ontario	R(D)
	<i>Oncorhynchus tshawytscha</i>	chinook salmon	Pacific	1873	all lakes but Superior	R(D)
	<i>Oncorhynchus mykiss</i>	rainbow trout	Pacific	1876	Lake Huron	R(D)
	<i>Salmo trutta</i>	brown trout	Eurasia	1883	Lakes Ontario and Michigan	R(A) R(D)
Poeciliidae	<i>Gambusia affinis</i>	western mosquitofish	Mississippi	1923	Cook Co., Illinois	R(D)
Gasterosteidae	<i>Apeltes quadracus</i>	fourspine stickleback	Atlantic	1986	Thunder Bay	S(BW)
Percichthyidae	<i>Morone americana</i>	white perch	Atlantic	1950	Cross Lake	C
Centrarchidae	<i>Enneacanthus gloriosus</i>	bluespotted sunfish	Atlantic	1971	Jamesville Res.	R(AQ), R(F)
	<i>Lepomis humilis</i>	orangespotted sunfish	Mississippi	1929	Lake St. Mary's	C
	<i>Lepomis microlophus</i>	redear sunfish	Southern U.S.	1928	Inland Indiana	R(D)
Percidae	<i>Gymnocephalus cernuus</i>	ruffe	Eurasia	1986	St. Louis River	S(BW)
Gobiidae	<i>Neogobius melanostomus</i>	round goby	Eurasia	1990	St. Clair River	S(BW)
	<i>Proterorhinus marmoratus</i>	tubenose goby	Eurasia	1990	St. Clair River	S(BW)

Mechanism codes: Deliberate release R(D); Unintentional release R(I); Aquarium release R(AQ); Cultivation release R(C); Fish release R(F); Accidental release R(A); Ballast water S(BW); Solid ballast S(SB); Fouling S(F); Canals (C); Railroads and Highways (RH)

Table 1 (Continued). Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic fauna of the Great Lakes

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Mollusks						
Valvatidae	<i>Valvata piscinalis</i>	European valve snail	Eurasia	1897	Lake Ontario	S(SB)
Viviparidae	<i>Cipangopaludina chinensis malleata</i>	Oriental mystery snail	Asia	1931	Niagara River	R(AQ)
	<i>Cipangopaludina japonica</i>		Asia	1940s	Lake Erie	R(D)
	<i>Viviparus georgianus</i>	banded mystery snail	Mississippi	<1906	Lake Michigan	R(AQ)
Hydrobiidae	<i>Potamopyrgus antipodarum</i>	New Zealand mud snail	New Zealand	1991	Lake Ontario	S(BW)
Bithyniidae	<i>Bithynia tentaculata</i>	faucet snail	Eurasia	1871	Lake Michigan	S(SB), R(D)
Hydrobiidae	<i>Gillia altilis</i>	snail	Atlantic	1918	Oneida Lake	C
Pleuroceridae	<i>Elimia virginica</i>	snail	Atlantic	1860	Erie Canal	C
Lymnaeidae	<i>Radix auricularia</i>	European ear snail	Eurasia	1901	Chicago	R(AQ), R(A)
Sphaeriidae	<i>Sphaerium corneum</i>	European fingernail clam	Eurasia	1952	Rice Lake	Unknown
	<i>Pisidium amnicum</i>	greater European pea clam	Eurasia	1897	Genesee	S(SB)
Corbiculidae	<i>Corbicula fluminea</i>	Asiatic clam	Asia	1980	Lake Erie	R(A), R(AQ), R(F)
Dreissenidae	<i>Dreissena polymorpha</i>	zebra mussel	Eurasia	1988	Lake St. Clair	S(BW)
	<i>Dreissena bugensis</i>	quagga mussel	Eurasia	1991	Lake Ontario	S(BW)
Unionidae	<i>Lasmigona subviridis</i>	mussel	Atlantic	<1959	Erie Canal	C
Crustaceans						
Cladocera	<i>Bythotrephes cederstroemi</i>	spiny water flea	Eurasia	1984	Lake Huron	S(BW)
	<i>Eubosmina coregoni</i>	water flea	Eurasia	1966	Lake Michigan	S(BW)
	<i>Cercopagis pengoi</i>	fish hook flea	Ponto-Caspian	1998	Lake Ontario	S(BW)
Copepoda	<i>Eurytemora affinis</i>	calanoid copepod	widespread	1958	Lake Ontario	S(BW)
	<i>Skistodiaptomus pallidus</i>	calanoid copepod	Mississippi	1967	Lake Ontario	R(A), R(F)
	<i>Argulus japonicus</i>	parasitic copepod	Asia	<1988	Lake Michigan	R(F), R(AQ)
Amphipoda	<i>Gammarus fasciatus</i>	gammarid amphipod	Atlantic	<1940	Unknown	S(BW), S(SB)
	<i>Echinogammarus ischnus</i>	gammarid amphipod	Ponto-Caspian	1995	Detroit River	S(BW)
Oligochaetes						
Naididae	<i>Ripistes parasita</i>	oligochaete	Eurasia	1980	North Channel	S(BW)
Tubificidae	<i>Branchiura sowerbyi</i>	oligochaete	Asia	1951	Kalamazoo River	R(A)
	<i>Phalodrilus aquaedulcis</i>	oligochaete	Eurasia	1983	Niagara River	S(BW)

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Ballast water S(BW); Solid ballast S(SB); Fouling S(F); Canals (C); Railroads and Highways (RH)

Table 1 (Continued). Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic fauna of the Great Lakes

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Other invertebrates						
Platyhelminthes	<i>Dugesia polychroa</i>	flatworm	Eurasia	1968	Lake Ontario	S(BW)
Hydrozoa	<i>Cordylophora caspia</i>	hydroid	Unknown	1956	Lake Erie	R(A)
	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Asia	1933	Lake Erie	R(A)
Insecta	<i>Acentropus niveus</i>	aquatic moth	Eurasia	1950	Lake Ontario, Erie	R(A)
	<i>Tanysphyrus lemnae</i>	aquatic weevil	Eurasia	<1943	Unknown	Unknown
Disease pathogens						
Bacteria	<i>Aeromonas salmonicida</i>	furunculosis	Unknown	<1902	Unknown	R(F)
Protozoa	<i>Glugea hertwigi</i>	microsporidian parasite	Eurasia	1960	Lake Erie	R(F)
	<i>Myxobolus cerebralis</i>	salmonid whirling disease	Unknown	1968	Ohio	R(F)
Present but not established						
Grapsidae	<i>Eriocheir sinensis</i>	Chinese mitten crab	northern China	1965	Detroit River	BW
Pleuronectidae	<i>Platyichthys flesus</i>	European flounder	ne Atl. Ocean; Black Sea	1974	Lake Erie	BW
Questionable						
Cambaridae	<i>Oronectes rusticus</i>	Rusty crayfish	Ohio River basin	1960	Wisconsin	bait

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Table 2. Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic plants and algae of the Great Lakes

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Algae						
Chlorophyceae	<i>Enteromorpha intestinalis</i>	green alga	Atlantic	1926	Wolf Creek (O)	R(A)
	<i>Enteromorpha prolifera</i>	green alga	Atlantic	1979	Lake St. Clair	Unknown
	<i>Nitellopsis obtusa</i>	green alga	Eurasia	1983	Lake St. Clair	S(BW)
Chrysophyceae	<i>Hymenomonas roseola</i>	coccolithophorid	Eurasia	1975	Lake Huron	S(BW)
Bacillariophyceae	<i>Actinocyclus normanii</i>	diatom	Eurasia	1938	Lake Ontario	S(BW)
	<i>fo. subsalsa</i>					
	<i>Biddulphia laevis</i>	diatom	widespread	1978	Lake Michigan	S(BW)
	<i>Cyclotella atomus</i>	diatom	widespread	1964	Lake Michigan	S(BW)
	<i>Chaetoceros honii</i>	diatom	unknown	1978	Lake Huron	S(BW)
	<i>Skeletonema potamos</i>	diatom	widespread	1963	Toledo, Ohio (E)	S(BW)
	<i>Skeletonema subsalsum</i>	diatom	Eurasia	1973	Sandusky Bay (E)	S(BW)
	<i>Stephanodiscus binderanus</i>	diatom	Eurasia	1938	Lake Michigan	S(BW)
	<i>Stephanodiscus subtilis</i>	diatom	Eurasia	1946	Lake Michigan	S(BW)
	<i>Thalassiosira guillardii</i>	diatom	widespread	1973	Sandusky Bay (E)	S(BW)
	<i>Thalassiosira lacustris</i>	diatom	widespread	<1978	Lake Erie	S(BW)
	<i>Thalassiosira pseudonana</i>	diatom	widespread	1973	Ohio (E)	S(BW)
	<i>Thalassiosira weissflogii</i>	diatom	widespread	1962	Detroit River	S(BW)
	<i>Thalassiosira baltica</i>	diatom	?	?	?	S (BW)
	<i>Diatoma ehrenbergii</i>	diatom	widespread	1930s	Lake Michigan	S(BW)
	<i>Cyclotella criptica</i>	diatom	widespread	1964	Lake Michigan	S(BW)
	<i>Cyclotella pseudostelligera</i>	diatom	widespread	1946	Lake Michigan	S(BW)
	<i>Cyclotella woltereki</i>	diatom	widespread	1964	Lake Michigan	S(BW)
	Phaeophyceae	<i>Sphacelaria fluviatilis</i>	brown alga	Asia	1975	Gull Lake (M)
<i>Sphacelaria lacustris</i>		brown alga	unknown	1975	Lake Michigan	S(BW)
Rhodophyceae	<i>Bangia atropurpurea</i>	red alga	widespread	1964	Lake Erie	S(BW), S(F)
	<i>Chroodactylon ramosum</i>	red alga	Atlantic	1964	Lake Erie	S(BW)
Submerged Plants						
Marsileaceae	<i>Marsilea quadrifolia</i>	European water clover	Eurasia	<1925	Cayuga Lake (O)	R(D)
Cabombaceae	<i>Cabomba caroliniana</i>	fanwort	Southern U.S.	1935	Kimble Lake (M)	R(AQ), R(A)
Brassicaceae	<i>Rorippa nasturtium aquaticum</i>	water cress	Eurasia	1847	Niagara Falls (O)	R(C)

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Table 2 (Continued). Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic plants and algae of the Great Lakes

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Haloragaceae	<i>Myriophyllum spicatum</i>	Eurasian watermilfoil	Eurasia	1952	Lake Erie	R(AQ), S(F)
Trapaceae	<i>Trapa natans</i>	water chestnut	Eurasia	<1959	Lake Ontario (t)	R(A), R(AQ)
Menyanthaceae	<i>Nymphoides peltata</i>	yellow floating heart	Eurasia	1930	Conneaut River (E)	R(A)
Hydrocharitaceae	<i>Hydrocharis morsus-ranae</i>	European frog-bit	Eurasia	1972	Lake Ontario	R(AQ), R(D), S(F)
Potamogetonaceae	<i>Potamogeton crispus</i>	curly pondweed	Eurasia	1879	Keuka Lake (O)	R(D), R(F)
Najadaceae	<i>Najas marina</i>	spiny naiad	Eurasia	1864	Onondaga Lake (O)	S(SB)
	<i>Najas minor</i>	minor naiad	Eurasia	1932	Lake Cardinal (E)	R(D)
Marsh Plants						
Chenopodiaceae	<i>Chenopodium glaucum</i>	oak leaved goose foot	Eurasia	1867	Onondaga Lake (O)	RH
Caryophyllaceae	<i>Stellaria aquatica</i>	giant chickweed	Eurasia	1894	Lake St. Clair	unknown
Polygonaceae	<i>Polygonum caespitosum</i>	bristly lady's thumb	Asia	1960	Ohio (E)	unknown
	<i>var. longisetum</i>					
	<i>Polygonum persicaria</i>	lady's thumb	Eurasia	<1843	widespread	unknown
	<i>Rumex longifolius</i>	yard dock	Eurasia	1901	Isle Royale (S)	R(C)
	<i>Rumex obtusifolius</i>	bitter dock	Eurasia	<1840	widespread	unknown
Brassicaceae	<i>Rorippa sylvestris</i>	creeping yellow cress	Eurasia	1884	Rochester, NY (O)	S(SB)
Primulaceae	<i>Lysimachia nummularia</i>	moneywort	Eurasia	1882	central NY (O)	R(C)
	<i>Lysimachia vulgaris</i>	garden loosestrife	Eurasia	1913	central NY (O)	R(C)
Lythraceae	<i>Lythrum salicaria</i>	purple loosestrife	Eurasia	1869	Ithaca, NY (O)	C, S(SB)
Onagraceae	<i>Epilobium hirsutum</i>	great hairy willow herb	Eurasia	1874	Ithaca, NY (O)	R(A), S(SB)
	<i>Epilobium parviflorum</i>	small flowered hairy willow herb	Eurasia	1966	Benzie Co., MI (M)	unknown
Apiaceae	<i>Conium maculatum</i>	poison hemlock	Eurasia	<1843	widespread	R(C)
Solanaceae	<i>Solanum dulcamara</i>	bittersweet nightshade	Eurasia	<1843	widespread	R(C)
Boraginaceae	<i>Myosotis scorpioides</i>	true forget-me-not	Eurasia	1886	central NY (O)	R(C)
Lamiaceae	<i>Lycopus asper</i>	western water horehound	Mississippi	1892	Lake Erie	R(A)
	<i>Lycopus europaeus</i>	European water horehound	Eurasia	1903	Lake Ontario	S(SB)
	<i>Mentha gentilis</i>	creeping whorled mint	Eurasia	1915	central NY (O)	R(C)
	<i>Mentha piperita</i>	peppermint	Eurasia	<1843	widespread	R(C)
	<i>Mentha spicata</i>	spearmint	Eurasia	<1843	widespread	R(C)
Scrophulariaceae	<i>Veronica beccabunga</i>	European brooklime	Eurasia	1915	Monroe Co., NY (O)	S(SB)

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Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Asteraceae	<i>Cirsium palustre</i>	marsh thistle	Eurasia	<1950	Lake Superior	unknown
	<i>Pluchea odorata</i>					
	<i>var. succulenta</i>	salt-marsh fleabane	Atlantic	<1950	central NY (O)	unknown
	<i>var. purpurescens</i>	salt-marsh fleabane	Atlantic	1916	Lake Erie (t)	R(A)
	<i>Solidago sempervirens</i>	seaside goldenrod	Atlantic	1969	Chicago (M)	R(A)
	<i>Sonchus arvensis</i>	field sow thistle	Eurasia	1865	central NY	R(A)
	<i>Sonchus arvensis</i>					
	<i>var. glabrescens</i>	smooth field sow thistle	Eurasia	1902	Ohio (E)	R(A)
Butomaceae	<i>Butomus umbellatus</i>	flowering rush	Eurasia	<1930	Detroit River (E)	S(SB)
Balsaminaceae	<i>Impatiens glandulifera</i>	Indian balsam	Asia	1912	Port Huron (H)	R(C)
Juncaceae	<i>Juncus compressus</i>	flattened rush	Eurasia	<1895	Cayuga Lake (O)	R(A)
	<i>Juncus gerardii</i>	black-grass rush	Atlantic	1862	Chicago	S(SB)
	<i>Juncus inflexus</i>	rush	Eurasia	1922	central, NY	unknown
Cyperaceae	<i>Carex acutiformis</i>	swamp sedge	Eurasia	1951	St. Joseph Lake (M)	unknown
	<i>Carex disticha</i>	sedge	Eurasia	1866	Belleville, Ontario (O)	S(SB)
	<i>Carex flacca</i>	sedge	Eurasia	1896	Detroit River	unknown
Poaceae	<i>Agrostis gigantea</i>	redtop	Eurasia	1884	Ontario (S)	R(C)
	<i>Alopecurus geniculatus</i>	water foxtail	Eurasia	1882	Lake Erie	R(C)
	<i>Echinochloa crusgalli</i>	barnyard grass	Eurasia	<1843	widespread	R(C), S(SB)
	<i>Glyceria maxima</i>	reed sweet-grass	Eurasia	1940	Lake Ontario	R(C), S(SB)
	<i>Poa trivialis</i>	rough-stalked meadow grass	Eurasia	<1843	widespread	R(C), S(SB)
	<i>Puccinellia distans</i>	weeping alkali grass	Eurasia	1893	Montezuma, NY (O)	S(SB), RH
Sparganiaceae	<i>Sparganium glomeratum</i>	bur reed	Eurasia	1936	Lake Superior	unknown
Typhaceae	<i>Typha angustifolia</i>	narrow leaved cattail	Eurasia	1880s	central NY (O)	C, R(A)
Iridaceae	<i>Iris pseudacorus</i>	yellow flag	Eurasia	1886	Ithaca, NY (O)	R(C)
Shoreline Trees and Shrubs						
Betulaceae	<i>Alnus glutinosa</i>	black alder	Eurasia	<1913	widespread	R(C)
Salicaceae	<i>Salix alba</i>	white willow	Eurasia	<1886	widespread	R(C)
	<i>Salix fragilis</i>	crack willow	Eurasia	<1886	widespread	R(C)
	<i>Salix purpurea</i>	purple willow	Eurasia	<1886	widespread	R(C)
Rhamnaceae	<i>Rhamnus frangula</i>	glossy buckthorn	Eurasia	<1913	Ontario	R(C)

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Ballast water S(BW); Solid ballast S(SB); Fouling S(F); Canals (C); Railroads and Highways (RH)