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Known lake sturgeon (*Acipenser fulvescens*) spawning habitat in the channel between lakes Huron and Erie in the Laurentian Great Lakes

By B. A. Manny and G. W. Kennedy

US Geological Survey, Great Lakes Science Center, Ann Arbor, MI, USA

Summary

Bottom substrates and overlying water at three sites where lake sturgeon were reported by others to spawn in the 160-km channel between lakes Huron and Erie were surveyed by boat just before or after the exact time of spawning in 2001 to determine the kinds of substrates present and differences in water quality at the sites. Substrates, examined and photographed using a high-resolution, underwater, video camera, were beds of either rounded cobble (10–40 cm in diameter) and coarse gravel (2–8 cm in diameter) of glacial origin or coal cinders (0.5–12 cm in diameter) of human origin, >1/4 ha in area and >0.3 m in thickness. Water quality, defined as percent of surface light reaching the bottom (range: 0.05–8.7%), Secchi disc depth (range: 2.5–6.5 m), and water current velocity (range: 0.35–0.98 m s^{-1}), differed more than 3-fold between the three sites. Although water depth at these sites (range: 9–12 m) was greater than in many rivers elsewhere used by lake sturgeon, the water current velocities at these sites were in the range in which lake sturgeon were reported to deposit eggs in two small Canadian rivers (0.1–1.1 m s^{-1}).

Introduction

Lake sturgeon (*Acipenser fulvescens*) were once abundant throughout the Great Lakes basin but are now rare or threatened with extinction in all states but one bordering the Great Lakes, owing to habitat loss, barriers to migration, and over-harvest (Houston, 1987; The Nature Conservancy, 1994; Auer, 1999; Bruch, 1999). In 1880, lakes Huron and St Clair annually produced over 1.8 million kilograms of lake sturgeon (Hay-Chmielewski and Whelan, 1997). In 1890, lake sturgeon were abundant in the Detroit River, and a 'caviar factory' was located at Algonac, Michigan on the St Clair River (Harkness and Dymond, 1961). Currently, harvest is slot-limited to one lake sturgeon per person per year from Michigan waters of the St Clair River and no sturgeon may be taken from Michigan waters of the Detroit River (MDNR, 2002).

Lake sturgeon are part of fish community objectives for several of the Great Lakes (Busiahn, 1990; Eschenroder et al., 1995; Stewart et al., 1999). However, in the Great Lakes basin, neither the St Clair River nor the Detroit River is among the 20 sites where lake sturgeon reproduce, and too little is known about remnant lake sturgeon stocks and the consequences of fishery management options to begin restoration of lake sturgeon populations (Holey et al., 2000). The 160-km channel connecting lakes Huron and Erie (Fig. 1) supports a population of free-ranging, river-spawning lake sturgeon (Haas and Thomas, 1999; Hill and Manny, 1999). The Michigan shore of this channel is highly developed for industry, navigation, and homes for the more than 4 million people who live in southeast Michigan (Edsall et al., 1988; Manny et al., 1988). Spawning lake sturgeon have been observed at three sites in the St Clair and Detroit rivers and, despite predation by other fish on their eggs, have produced fry at one site (Nichols et al., 2002, in press). Characterization of spawning substrates is recognized as important in the restoration of lake sturgeon populations in Michigan (Hay-Chmielewski and Whelan, 1997) but few detailed descriptions of lake sturgeon spawning substrates are found in the literature and little was known about spawning habitat conditions at these three sites that could affect survival of lake sturgeon eggs and fry. We reasoned that protection of demersal sturgeon eggs and fry from predators and dislocation by water currents would be a function of the relative amount of interstitial void space present among bottom substrates. We also reasoned that survival of sturgeon eggs and fry would be a function of the amount of silt and decomposing organic matter present on the spawning substrates because they could reduce dissolved oxygen available for egg and fry survival (cf. Manny and Edsall, 1989). Lastly, our null hypothesis was that spawning by lake sturgeon in this highly urbanized channel was unrelated to water quality. Hence, our research objectives were to survey and describe the composition and arrangement of river bottom substrates, and to compare water quality at three known sturgeon spawning sites in this channel.

Materials and methods

Before our investigation, three active spawning sites of lake sturgeon were located by others near Port Huron, Michigan (42°59′50″N, 82°25′30″W) using scuba diving (K. Johnson and G. Lashbrook, pers. comm., 1999); near Algonac, Michigan (42°37′15″N, 82°35′00″W) using set lines and egg traps (Haas and Thomas, 1999; Nichols et al., 2002, in press) and near Zug Island, Michigan (42°17′13″N, 83°06′13″W) using ultrasonic telemetry and egg traps (Caswell et al., 2002, Fig. 1). These investigators provided us with geographic coordinates where lake sturgeon spawned in 2000 or 2001. The areal extent of these three spawning sites has been estimated by others to be 160 000 m^2, 2500 m^2, and 15 000 m^2, respectively (Nichols et al., 2002, in press; Caswell et al., 2002). In 2001, lake sturgeon spawned at these sites when water temperature reached 13°C on May 9, 2001 at Zug Island and on June 8, 2001 at the other two sites (US Geological Survey, unpubl. data). We surveyed bottom substrates before the actual spawning period at the Port Huron and Algonac sites on May 2–3, 2001 and after the actual spawning period at the Zug Island site on June 20, 2001. Bottom substrates were examined

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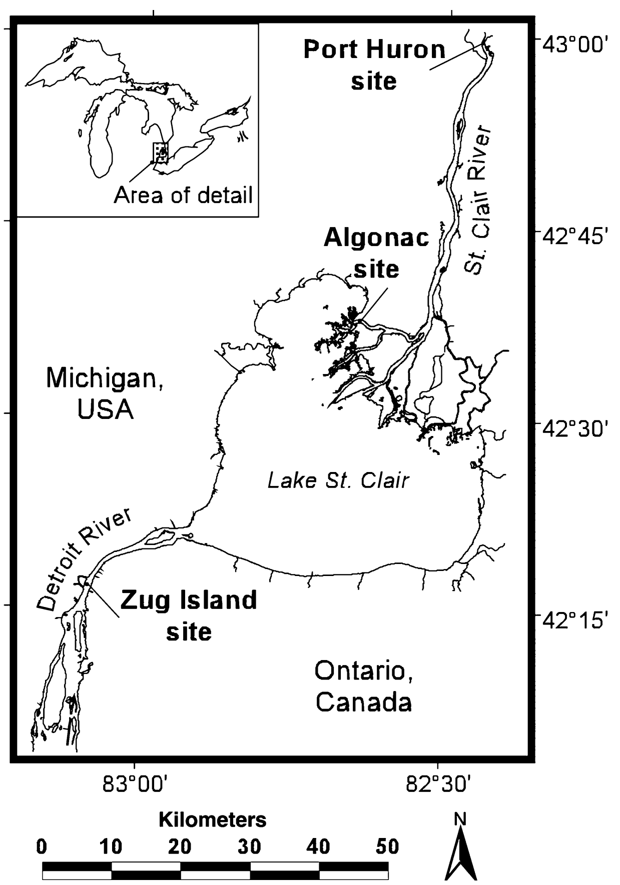

Fig. 1. Locations of known lake sturgeon spawning habitat off Port Huron, Algonac, and Zug Island in Michigan waters of the channel connecting lakes Huron and Erie

and photographed under ambient light conditions with a high-resolution, underwater, video camera (DeepSea Power & Light, Multi-SeaCam 1050, San Diego, CA) attached to a 14-kg depressor plate, as boat movements were recorded in time and space using a global positioning system unit (Trimble Model ProXR, Sunnyvale, CA), following Edsall et al. (1997). At each site, we traversed three to six transects, each 0.5–0.9 km in length, passing directly over substrates where spawning sturgeon had been observed or where sturgeon eggs had been collected in egg traps by others. The camera, attached by coaxial cable to a 30 × 30-cm television monitor onboard, was deployed from a boat while drifting downstream. Camera position was maintained continuously <0.25 m from the river bottom, directly beneath the boat, so that we could view the bottom substrates on the monitor while we recorded their images on video tape. Water temperature, water depth, water transparency, and light penetration were measured at geographic coordinates, where others reported that lake sturgeon spawned, using a glass-stem mercury thermometer (Fisher Scientific, Model 14-983-10B, Chicago, IL), boat-mounted depth sounder (Garmin International, Model 125 GPS Sounder, Olathe, KS), Secchi disc, and a 4-π underwater photometer (Protomatic, Model 1, Dexter, MI; cf. Rich and Wetzel, 1969) during mid-day respectively, while drifting. Light penetration was expressed as a percentage of surface light reaching the bottom of the water column. Water current velocity was measured with a portable, electric, water current meter (Marsh McBirney, Model 201, Frederick, MD) attached to a 7-kg weight at the surface (~0.5 m depth) and bottom of the water column, while at anchor. Diameters of bottom substrate particles collected at randomly selected locations on the camera transects with a bottom (PONAR) grab were measured with a 1-m ruler. One measurement of each of the above variables was made at each spawning site. We did not measure dissolved oxygen concentration in the water at the spawning sites because dissolved oxygen concentrations in waters throughout both the St Clair and Detroit Rivers (6.5–11.2 mg L^{-1}; Edwards et al., 1989; McClain and Manny 2000) are consistently higher than the minimum concentration needed to maintain fish populations (5.0 mg L^{-1}; Davis et al., 1979). Interstitial void space within the bottom substrates was estimated by visual inspection of video images of bottom substrates, not by measuring the depths of bottom substrates overlaying the hard clay bottom of the river bed. Estimation of the depth of interstitial void space in sturgeon spawning substrates included in this study was largely based on our prior experience in estimating the interstitial depth of a wide variety of substrates used for spawning by lake trout in the Great Lakes (Manny and Edsall 1989; Edsall et al., 1992; Manny et al., 1995). The bed of coal cinders at the Algonac site was determined earlier by divers to be up to 2 m thick (Nichols et al., 2002, in press). Because fish use and spawning densities of lake sturgeon at these three sites are not known, we could not relate fish use or spawner density to substrate type or conditions at these three sites.

Results

We recorded 90, 60, and 65 min of bottom substrate images on video tape at Port Huron, Algonac, and Zug Island, respectively. Analyses of those images revealed that substrates at Port Huron (Fig. 2) were composed of a mixture of rounded, igneous, coarse gravel (3–8 cm in diameter) and cobble (10–30 cm in diameter), arranged in a contiguous bed, over a large area (>67 ha). Substrates at Algonac (Fig. 3) were composed of coal cinders of human origin, 0.5–12 cm in diameter, arranged in one contiguous bed up to 2 m thick (cf. Nichols et al., 2002 in press), covering only a small area (0.25 ha). Substrates at Zug Island (Fig. 4) were composed of a contiguous bed of coal cinders of human origin, 1–4 cm in diameter, and an adjacent contiguous bed of rounded, coarse gravel (2–8 cm in diameter) of glacial origin, that covered a total area of 1.5 ha. By visual inspection of video images, we estimated that 85, 90, and 90% of the areal extent of bottom substrates at Port Huron, Algonac, and Zug Island, respectively, possessed enough interstitial, void space (>30 cm; Edsall et al., 1989; Edsall et al., 1992) to adequately protect lake sturgeon eggs and fry from predation and dislocation during incubation. Cobble and gravel beds at Port Huron were free of all sand and silt. On May 2, 2001, prior to spawning by lake sturgeon, cinders at Algonac were covered with zebra mussels (*Dreissena polymorpha*), periphyton, and silt (Fig. 3a). However in previous years, before sturgeon spawned there, cinders at this site were cleaned of all periphyton and silt by redhorse suckers (*Moxostoma* spp.; Fig. 3b; cf. Nichols et al., 2002, in press). On June 20, 2001, 6 weeks after sturgeon spawned at Zug Island, cinders and gravel were covered by a small amount of periphyton and silt (Fig. 4). We saw no macrophytic plants or decaying organic matter on substrates at any of these three sites.

Percentage of surface light reaching the bottom (range; 0.5–8.7%), Secchi depth (range: 2.5–6.5 m), and water current velocity (range: 0.33–0.98 m s^{-1}) decreased with distance

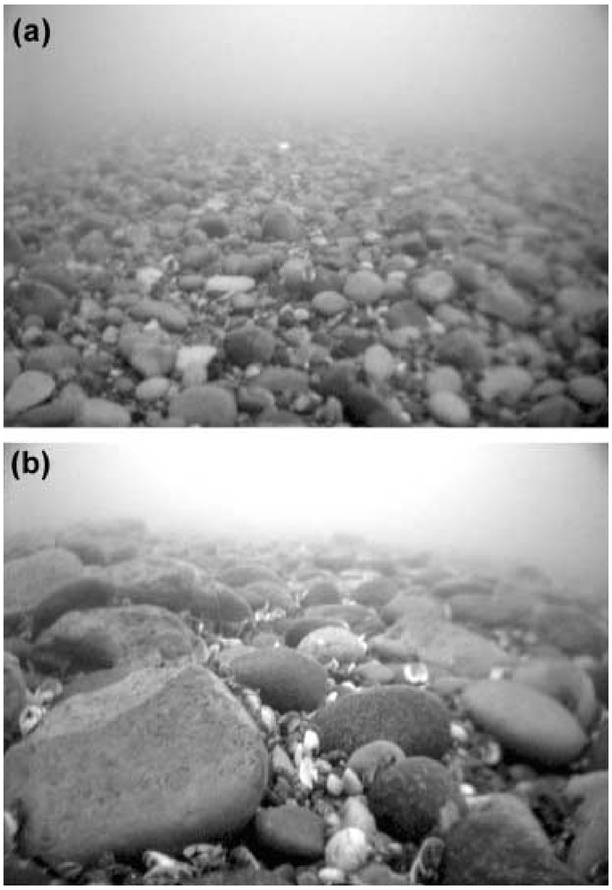

Fig. 2. Bottom substrates and their arrangement in the St Clair River at Port Huron, Michigan. (a) Coarse gravel; and (b) Cobble and gravel

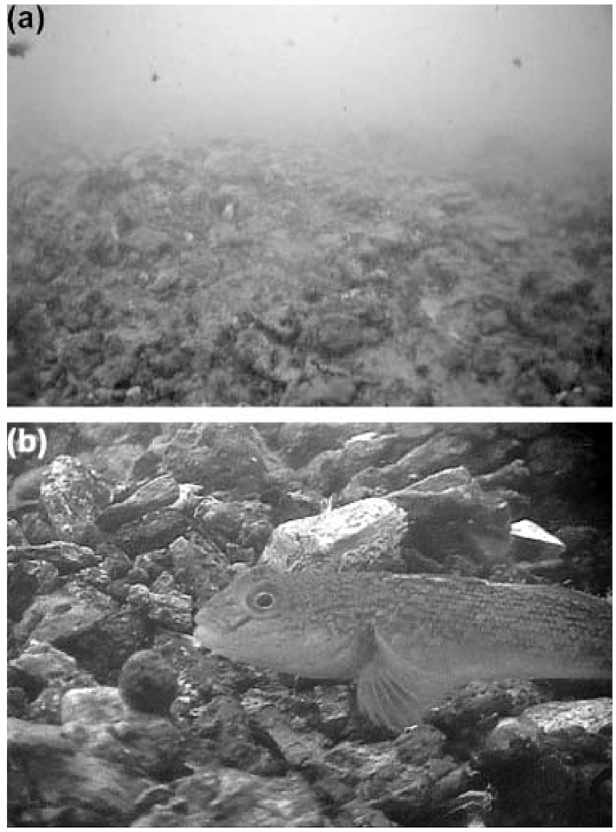

Fig. 3. Bottom substrates and their arrangement in the St Clair River at Algonac, Michigan. (a) before; and (b) after substrates are cleaned by suckers. Shown among the cinders is a round goby (*Neogobius melanostomus*)

downstream in the channel and were 3-fold greater at Port Huron than at Zug Island (Table 1). Water depth that we measured at geographic coordinates where sturgeon were reported by others to have spawned at each site (range: 9–12 m) was greatest at Port Huron, intermediate at Zug Island, and least at Algonac (Table 1). Estimated substrate bed thickness (0.3–2.0 m) was greatest at Algonac, intermediate at Port Huron, and least at Zug Island (Table 1). Water current velocity at the surface of the water column (range: 0.33–0.98 m s^{-1}) was the same or slightly lower than velocity at the bottom of the water column at each spawning site (Table 1). Measured water temperatures (8.5–20.3°C; Table 1) indicate that our survey preceded optimum spawning temperatures (13–15°C; Scott and Crossman, 1973) at Port Huron and Algonac. Sturgeon spawned 6 weeks before our survey at Zug Island (Caswell et al., 2002).

Discussion

Characterization of substrates presently used by spawning lake sturgeon is recognized as important in the restoration of lake sturgeon populations in Michigan (Hay-Chmielewski and Whelan, 1997). We reasoned that protection of demersal sturgeon eggs and fry from predation and dislocation would be provided by 30 cm or more of interstitial void space present among bottom substrates because that interstitial depth has been found to protect demersal lake trout eggs (Edsall et al., 1992) that are larger in diameter than and lack the sticky coating possessed by lake sturgeon eggs (Scott and Crossman, 1973). We further reasoned that successful development and hatch of sturgeon eggs and fry would be reduced in proportion to the amount of silt and decomposing organic matter present on the spawning substrates because the latter would reduce dissolved oxygen available for egg and fry survival (cf. Manny and Edsall, 1989; Manny et al., 1995). Owing to the lack of any data on survival of lake sturgeon eggs and fry at two of these sites, we could not relate the composition and arrangement of bottom substrates or the relative amount of silt and decomposing organic matter on such substrates to the survival of sturgeon eggs or fry at these three sites.

Minimum habitat criteria of spawning lake sturgeon were recently defined by Bruch and Binkowski (2002) as: (i) clean, rocky substrates layered to provide interstitial, void space; (ii) water current velocity in excess of 0.5 m s^{-1}; (iii) water temperature of 12–16°C, and (iv) accessible to adults. The multiple layers of clean, metamorphic rocks and coarse gravel and/or coal cinders used by lake sturgeon at three spawning sites in this channel satisfy the first criteria above and closely resemble substrates reportedly used by spawning lake sturgeon elsewhere (Scott and Crossman, 1973; Baker, 1980; Kempinger, 1988; Lane et al., 1996; Slade and Auer, 1997; Baker and Borgeson, 1999). Furthermore, cinders and till deposits near Zug Island closely resemble in size and arrangement the cinder substrate near Algonac, Michigan, and till substrates near Port Huron, Michigan, where lake sturgeon spawn in the St Clair River (Nichols et al., 2002, in press; Caswell et al., 2002). The areal extent and thickness of deposits of coal cinders and gravel/cobble substrates at these three known spawning sites greatly exceed those present at the six and seven reputed, historic, sturgeon spawning sites elsewhere in the St Clair and

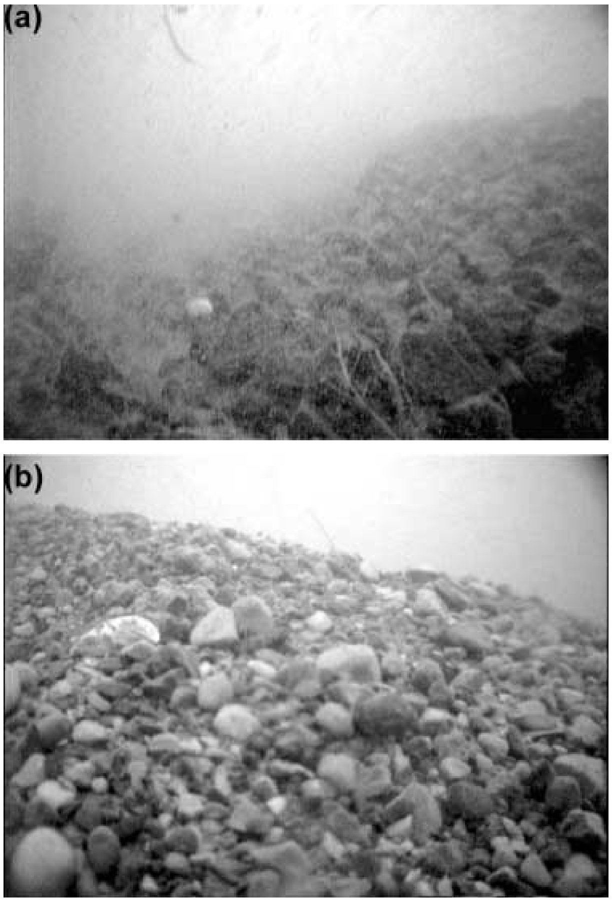

Fig. 4. Bottom substrates and their arrangement in the Detroit River at Zug Island, Michigan. (a) Cinders; and (b) Coarse gravel

Detroit Rivers, respectively (Goodyear et al., 1982), that have been recently surveyed with side-scan sonar and an underwater camera (US Geological Survey, unpubl. data). At all three sites, the composition and arrangement of substrates provided a large area of hard, clean material in beds thick enough to possess at least 30 cm of interstitial, void space that is flushed by above-average water velocity. Such composition and arrangement of substrates in areas of high water velocity are present over a large area in the upper St Clair River, at several smaller areas in the lower St Clair River, and at a few small areas in the Detroit River (US Geological Survey, unpubl. data). The extent and distribution of such substrates in areas of high enough water velocity may limit the spawning habitat available to lake sturgeon and thus their ability to reproduce in this channel.

Water current velocity at the Port Austin and Algonac sites near the actual time of spawning (range: 0.53–0.98 m s^{-1}) satisfies the second criteria above but the velocity at Zug Island (mean: 0.35 m s^{-1}) was not that high. Even so, water velocity at all three sites fell within the range that lake sturgeon were reported to deposit eggs in two small Canadian rivers (0.1–1.09 m s^{-1}; LaHaye et al. 1992). Water velocity varies little from year to year at sturgeon spawning sites in this channel because discharge in this channel varies little, averaging 5121–5200 m^3 s^{-1}; and, ranging from 4250–4400 m^3 s^{-1} in February to 5444–5700 m^3 s^{-1} in August (Edsall et al., 1988; Manny et al., 1988). Water temperature in this channel satisfies the third criteria above (range: 0.5–25.5°C); usually reaching 13–15°C in May in the Detroit River (Manny et al., 1988) and in June in the St Clair River (Edsall et al., 1988).

Waters at all sites in this channel satisfy the fourth criteria above because there are no barriers to sturgeon movements. This channel may be relatively important for spawning and reproduction to lake sturgeon in the Great Lakes because historic lake sturgeon spawning habitat in many tributaries to the Great Lakes is not accessible, because of the construction of dams that restrict upstream sturgeon movements (Rochard et al. 1990).

Although not an important criteria for spawning lake sturgeon, water depths at these three spawning sites (9–12 m) exceed depths at which lake sturgeon are reported to spawn elsewhere [depth ranges: 0.6–4.6 m in Scott and Crossman (1973); 1.8–3.6 m in Kempinger (1988); 0.1–1.6 m in LaHaye et al., (1992)], perhaps because, compared with smaller rivers, this channel is wider and deeper (700–1000 m and 9–17 m, respectively; Edwards et al., 1989). Because light penetration and water current velocity decreased more than threefold with distance downstream between sites where lake sturgeon spawned in this channel we conclude that sturgeon spawn over a wide range of water quality in this channel. More quantitative data on measured interstitial void space present within the observed bottom substrates at these spawning sites, and on survival of sturgeon eggs and fry relative to the amount of silt and periphyton on different types of bottom substrates used by spawning lake sturgeon in this channel, would better focus the construction or restoration of successful spawning sites for lake sturgeon throughout the Great Lakes basin.

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Table 1
Habitat characteristics of three known spawning sites of lake sturgeon in Michigan waters of the channel between lakes Huron and Erie

Site name	Date sampled	Substrate type	Substrate bed thickness (m)	Water depth (m)	Water temp. (°C)	Secchi depth (m)	Light penetration (%)	Water current velocity (m s^{-1})	
								Surface	Bottom
Port Huron	May 3, 01	Igneous cobble and coarse gravel	0.5–1.0	12.2	8.5	6.5	8.7	0.98	0.98
Algonac	May 2, 01	Coal cinders	0.5–2.0	9.1	8.5	2.6	5	0.53	0.53
Zug Island	Jun 20, 01	Coal cinders and coarse gravel	0.3–1.0	10.4	20.3	2.5	0.05	0.33	0.36

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Author's address: Dr B. Manny, Great Lakes Science Center, 1451 Green Road, Ann Arbor, MI 48105-2897, USA.
E-mail: bruce_manny@usgs.gov