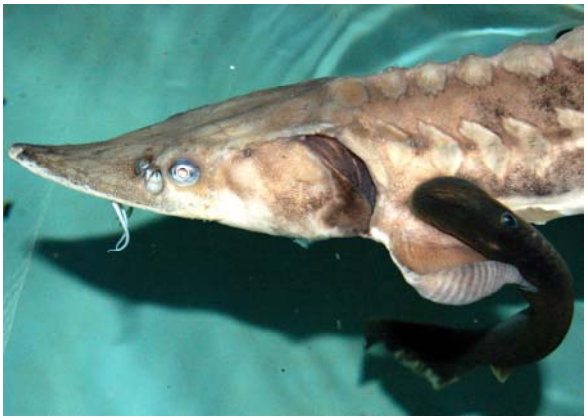
APPLICATION OF A DICHOTOMOUS KEY TO THE CLASSIFICATION OF SEA LAMPREY *PETROMYZON MARINUS* MARKS ON LAKE STURGEON *ACIPENSER FULVESCENS*



Great Lakes Fishery Commission

Miscellaneous Publication 2007-02

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, which was ratified on October 11, 1955. It was organized in April 1956 and assumed its duties as set forth in the Convention on July 1, 1956. The Commission has two major responsibilities: first, develop coordinated programs of research in the Great Lakes, and, on the basis of the findings, recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; second, formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

The Commission is also required to publish or authorize the publication of scientific or other information obtained in the performance of its duties. In fulfillment of this requirement the Commission publishes the Technical Report Series, intended for peer-reviewed scientific literature; Special Publications, designed primarily for dissemination of reports produced by working committees of the Commission; and other (non-serial) publications. Technical Reports are most suitable for either interdisciplinary review and synthesis papers of general interest to Great Lakes fisheries researchers, managers, and administrators, or more narrowly focused material with special relevance to a single but important aspect of the Commission's program. Special Publications, being working documents, may evolve with the findings of and charges to a particular committee. Both publications follow the style of the *Canadian Journal of Fisheries and Aquatic Sciences.* Sponsorship of Technical Reports or Special Publications does not necessarily imply that the findings or conclusions contained therein are endorsed by the Commission.

COMMISSIONERS

December 2007

APPLICATION OF A DICHOTOMOUS KEY TO THE CLASSIFICATION OF SEA LAMPREY *PETROMYZON MARINUS* MARKS ON LAKE STURGEON *ACIPENSER FULVESCENS*

Holly K. Patrick[1]
Purdue University
Department of Forestry & Natural Resources
195 Marsteller St.
West Lafayette, Indiana 47907

Trent M. Sutton[2]
Purdue University
Department of Forestry & Natural Resources
195 Marsteller St.
West Lafayette, Indiana 47907

William D. Swink
U. S. Geological Survey
Great Lakes Science Center
Hammond Bay Biological Station
11188 Ray Road
Millersburg, Michigan 49759

Citation: Patrick, H.K., T.M. Sutton, and W.D. Swink. 2007. Application of a dichotomous key to the classification of sea lamprey marks on lake sturgeon *Acipenser fulvescens*. Great Lakes Fish. Comm. Misc. Publ. 2007-02. Available from http:www.glfc.org/pubs/pub.htm#misc [accessed—add date you accessed].

Great Lakes Fishery Commission
2100 Commonwealth Blvd., Suite 100
Ann Arbor, MI 48105-1563

December 2007

ISSN: 1090-106x (print)
1553-8087 (online)

---

[1]Present address: Great Lakes Fishery Commission, 2100 Commonwealth Blvd., Suite 100, Ann Arbor, Michigan 48105-1563.

[2]Present address: University of Alaska Fairbanks, School of Fisheries & Ocean Sciences, 245 O'Neill Building, P.O. Box 747220, Fairbanks, Alaska, 99775-7220.

[1]Corresponding author (e-mail: hpatrick@glfc.org)

TABLE OF CONTENTS

INTRODUCTION

The current sea lamprey (*Petromyzon marinus*) mark classification system used for Great Lakes fishes was originally developed based on lake trout (*Salvelinus namaycush*) (King 1980). This scheme recognizes two basic types of sea lamprey marks (Types A and B) and four stages of mark healing (I-IV). Type-A marks indicate that the skin at the attachment site is broken, and the underlying musculature is exposed, whereas Type-B marks indicate that the skin is not broken. Stage I indicates that the parasite has recently detached and no healing has taken place, Stages II and III indicate intermediate stages of healing, and Stage IV represents complete healing. This classification system was recently revised by Ebener et al. (2006) for other Great Lakes fishes using images of sea lamprey marks on lake trout, lake whitefish (*Coregonus clupeaformis*), cisco (*C. artedi*), walleye (*Sander vitreus*), Chinook salmon (*Oncorhynchus tshawytscha*), and white sucker (*Catostomus commersoni*). The photographic illustrations in the King (1980) classification system were representative of idealized types and stages of sea lamprey marks. In contrast, the revised system by Ebener et al. (2006) also includes photographic illustrations of more complicated marks, such as multiple and sliding marks and photos of marks caused by agents other than sea lamprey, such as double-crested cormorants (*Phalacrocorax auritus*) or pathogens, which can be easily misinterpreted as sea lamprey marks. Although the Ebener et al. (2006) system will be beneficial for classifying sea lamprey marks on most Great Lakes fishes, this system may not be applicable for lake sturgeon (*Acipenser fulvescens*).

A specific classification system is needed for lake sturgeon because this species differs in life history and morphology from other Great Lakes fishes. Particular characteristics of lake sturgeon, such as the scutes and large body size, may provide a survival advantage during and following a sea lamprey attack. In addition, lake sturgeon appear to exhibit more complete and rapid rates of mark healing following a sea lamprey attack than do other fishes (R. Elliott, U.S. Fish and Wildlife Service, Green Bay Fishery Resources Office, 2661 Scott Tower Dr., New Franken, WI, 54229, personal communication; Patrick 2007). To ensure consistency, the types and stages of sea lamprey marks used in assessing marking on lake sturgeon should be similar to those used in the King (1980) and Ebener et al. (2006) classification systems. The King (1980) scheme has been used in the Great Lakes for over 25 years, so ensuring that a lake sturgeon classification system is consistent with the existing scheme will increase the likelihood of incorporating it into ongoing assessment programs. A tentative sea lamprey mark classification system for lake sturgeon was recently devised and consists of two types and four stages of sea lamprey marks (R. Elliott, unpubl. data). However, this scheme is based strictly on observations of sea lamprey marks on field-caught lake sturgeon, where the interval of mark healing cannot be known. Illustrating the stages of mark healing is difficult without a time frame for reference. Further, it was unclear when or whether pigmentation returns to a mark site on an affected lake sturgeon following a sea lamprey attack, even for a completely healed mark. Observing the healing process of sea lamprey marks on lake sturgeon in a laboratory setting provides a time frame for mark healing and an opportunity to observe the extent of re-pigmentation of these sites.

Our objective was to develop a sea lamprey mark classification scheme for lake sturgeon. In a laboratory experiment, we evaluated the rate of mark healing and scar retention of lake sturgeon hosts following a single sea lamprey attack and developed a photographic dichotomous key for sea lamprey marks on lake sturgeon. The testable hypotheses of this study were:

1. The rate of mark healing and scar retention by lake sturgeon following a single sea lamprey attack will be the same as observations for lake trout
2. The classification system used for lake sturgeon following a single sea lamprey attack will differ from existing schemes

This dichotomous key will augment the existing classification schemes and will help to increase consistency for collecting data on sea lamprey marks on lake sturgeon.

DEVELOPMENT AND APPLICATION OF CRITERIA

Four size-classes of lake sturgeon were used in a laboratory study to assess mark healing and scar retention following a single sea lamprey attack and to develop a sea lamprey mark classification system. Sample sizes for each length category included 24 fish for size-class I (470-570-mm fork length (FL)), 21 fish for size-class II (570-650-mm FL), 17 fish for size-class III (650-760-mm FL), and 12 fish for size-class IV (950-1550-mm FL). To identify individual lake sturgeon throughout the experiment, passive integrated transponder tags (20 mm x 3.2 mm, 125 kHz; Biomark Inc., 703 South Americana Boulevard, Boise, ID, 83702) were implanted subcutaneously beneath the third lateral scute on the left side of each fish using an 8-gauge needle and syringe (Patrick 2007).

Prior to the start of each experimental trial, one lake sturgeon and one sea lamprey were removed from their respective holding tanks, anesthetized in a 70 mg/L solution of tricaine methanesulfonate, measured for FL (lake sturgeon) or total length (sea lamprey) to the nearest 1 mm, and weighed to the nearest 0.01 g. Upon recovery from anesthesia, the lake sturgeon and sea lamprey were placed into one of five 2,177-L flow-through fiberglass circular experimental tanks supplied with supplemental aeration. Four of the five experimental tanks were divided using a 183-cm long x 74-cm high screen with 1-mm bar mesh. The experimental tank without a divider was used to accommodate experimental trials for larger lake sturgeon in size-class III. For their experimental trials, size-class IV lake sturgeon were placed into a 9,028-L flow-through fiberglass circular tank supplied with supplemental aeration (Patrick 2007).

Observations to check for sea lamprey attachments and detachments were made daily at 0700, 1200, and 1700 hours. When an attachment was observed, the date, time, and location of attachment (Fig. 1) were recorded.

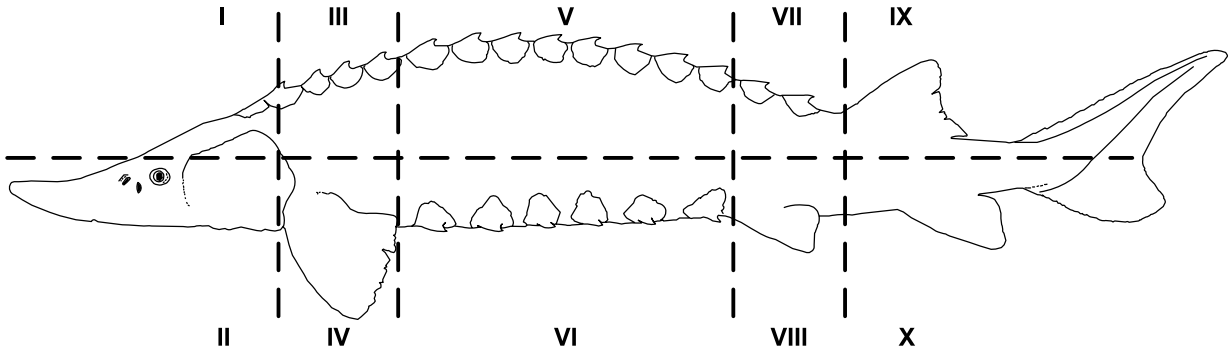


Fig. 1. Body regions of lake sturgeon used to classify the location of sea lamprey attachment.

Sea lamprey were allowed to feed on lake sturgeon until detachment or mortality of the host or parasite, and each sea lamprey was permitted only one attachment event per host. Lake sturgeon, regardless of their fate following a sea lamprey attack, were removed from the tank, weighed and measured, and replaced with another lake sturgeon. The removed lake sturgeon were transferred to a 2,177-L flow-through fiberglass circular recovery tank supplied with supplemental aeration to assess delayed mortality (Patrick 2007).

Images of sea lamprey-inflicted marks on lake sturgeon were captured with a Cannon EOS 350D digital camera (Canon U.S.A., Inc., One Canon Plaza, Lake Success, NY, 11042) immediately following parasite detachment. These images were also captured for each lake sturgeon once per week during the two-week short-term recovery period and once per month during the six-month long-term recovery period until the mark was healed and no longer visible. Each photo session involved anesthetizing the lake sturgeon, as described previously, capturing digital images of the sea lamprey mark, and documenting details of the mark-healing process. If a lake sturgeon death occurred prior to the detachment of the sea lamprey or during one of the recovery periods, a digital image of the fish was captured as immediately as possible following detection of the death. A photographic time line of the sequential healing process was created for each individual fish. These images were used to develop a set of lake sturgeon-specific typing and staging criteria for sea lamprey marks similar to those developed by King (1980), Ebener et al. (2006), and R. Elliott (unpubl. data). The development of this photographic dichotomous classification key was based on these images (Patrick 2007).

MARK CLASSIFICATION

The characteristics of sea lamprey attachments on lake sturgeon hosts and the subsequent healing of these marks are different from the marks typically found on salmonid species after an attack and during the healing process. As a result, the sea lamprey mark classification system described by King and Edsall (1979) and Ebener et al. (2006) was modified for the specific application to lake sturgeon. The primary characteristics used in the aforementioned classification system that are not applicable for classifying sea lamprey marks on lake sturgeon are the presence/absence of scales and/or scale pockets and degree of scale regeneration. On lake sturgeon, pigmentation around the margins of the mark was darker than before the attack for Type-A and Type-B marks during the healing process. This characteristic has not been reported for other fish species following a sea lamprey attack (King and Edsall 1979; Ebener et al. 2006). We characterize below the type and stage of sea lamprey marks observed on lake sturgeon.

Type A

Stage I

The sea lamprey has recently detached (within the last 7 d) and no healing is evident. The specific criteria for a Type-A, Stage-I mark include:

- A definite perforation (pit) exists through the skin/scutes
- The musculature may or may not be exposed
- The skin surrounding the attachment site is rough to the touch
- The skin surrounding the attachment site is white, necrotic, and ragged with no sign of healing
- Yellowish discoloration may be present around the margins of the attachment site
- Some or all of the barbels may be absent on marks on the ventral surface of the rostrum

Bleeding has often been observed for field-caught fish from a fresh Type-A sea lamprey mark (Ebener et al. 2006). However, this characteristic was not noted in our study or in the laboratory study by King and Edsall (1979). A Type-A mark with a perforation can either expose the musculature (Figs. 2, 3) or not expose the musculature (Figs. 4, 5). Examples of Type-A, Stage-I sea lamprey marks and associated features on lake sturgeon are in Figs. 6-9.

Stage II

The sea lamprey attack occurred recently (within the past 30 d) and healing has begun. A membrane-like material covers the entire sea lamprey attachment site making it smooth to the touch. The specific criteria for a Type-A, Stage-II mark include:

- A pit is present
- The musculature, if exposed, is usually pink
- The skin surrounding the attachment site is smooth to the touch
- The entire attachment site is covered with a transparent, membrane-like material, and a semi-opaque mucus-like material can be seen partly filling the pit
- Hemorrhaging may exist around the margins of the attachment site
- No yellowish discoloration is present around the margins of the attachment site
- Barbels have begun to regenerate if they were lost previously

Examples of Type-A, Stage-II sea lamprey marks and associated features on lake sturgeon are in Figs. 10-13.

Stage III

The attachment site is similar to that described for Stage II, except that the hemorrhaging and yellowish discoloration around the attachment site have disappeared and dark-pigment cells surrounding the exposed musculature are evident. The specific criteria for a Type-A, Stage-III mark include:

- A pit can still be felt but has diminished in depth and diameter
- Hemorrhaging and yellow discoloration are no longer present around the margins of the attachment site
- Dark-cell masses often develop around the attachment site if the mark is on the dorsal surface or restoration of initial pigment color occurs for ventrally located marks

Examples of Type-A, Stage-III sea lamprey marks and associated features on lake sturgeon are in Figs. 14-17.

Stage IV

The sea lamprey mark is no longer evident on the host and is healed. The specific criteria for a Type-A, Stage-IV mark include:

- Differentiation between the attachment site and adjacent areas of the fish is difficult
- A pit or indentation may still be felt but not seen

Examples of Type-A, Stage-IV sea lamprey marks and associated features on lake sturgeon are in Figs. 18, 19.

Type B

Stage I

The sea lamprey has recently detached (within the last 7 d), and no healing is evident. The specific criteria for a Type-B, Stage-I mark include:

- The skin is largely intact, but an abrasion or broken blood vessels are evident
- The underlying musculature is not exposed (no perforation or pit can be felt or seen)
- The skin surrounding the attachment site is rough and firm to the touch
- Little or no swelling is evident

For an example of a Type-B mark, see Fig. 4. Examples of Type-B, Stage-I sea lamprey marks and associated features on lake sturgeon are in Figs. 20-23.

Stage II

The sea lamprey attack was recent (within the past 30 d). Healing has begun, and a membrane-like material covers the entire attachment site making it smooth to the touch. The specific criteria for a Type-B, Stage-II mark include:

- The skin surrounding the attachment site is smooth to the touch
- The entire attachment site is covered with a transparent, membrane-like material
- Yellowish discoloration may be present around the margins of the attachment site

Examples of Type-B, Stage-II sea lamprey marks and associated features on lake sturgeon are seen in Figs. 24-27.

Stage III

The attachment site is smooth to the touch and appears slightly discolored or lightly blanched compared to adjacent areas. The specific criteria for a Type-B, Stage-III mark include:

- Hemorrhaging and yellow discoloration are no longer present around the margins of the attachment site
- Dark-cell masses often develop around the attachment site if the mark is on the dorsal surface, or restoration of original pigment color occurs for ventrally-located marks

Examples of Type-B, Stage-III sea lamprey marks and associated features on lake sturgeon are in Figs. 28-31.

Stage IV

The sea lamprey mark is barely evident and is essentially healed. The specific criteria for a Type-B, Stage-IV mark include pigmentation that has completely returned (often darker than usual if the attachment site is on the dorsal surface, or restoration of initial pigment color occurs for ventrally located marks)

Examples of Type-B, Stage-IV sea lamprey marks and associated features on lake sturgeon are in Figs. 32, 33.

Type B, Stages-I or -II Sloughing

The specific criteria for this mark are similar to those described for a Type-B, Stage-I or -II mark, however:

- The attachment site is inflamed and aggravated
- A pit can be felt beneath the skin in the musculature
- The skin covering the pit may slough off, exposing the musculature and giving the appearance of a Type-A, Stage-I or –II mark

An example of a Type-B, Stage-I or –II sloughing sea lamprey mark on a lake sturgeon is in Fig. 5.

DICHOTOMOUS KEY FOR CLASSIFYING SEA LAMPREY MARKS ON LAKE STURGEON

1a.	Pit:	• Definite perforation (pit) exists through the skin/scutes • Musculature may or may not be exposed 2
1b.	Pit absent:	• Skin is largely intact, but an abrasion or broken blood vessels are evident • Skin may slough off, exposing the musculature; but there is no perforation 5

Fig. 2. Example of marks with perforations through the skin exposing muscle.

Fig. 3. Example of marks with perforations through the skin not exposing muscle.

Fig. 4. Example of marks with no perforation through the skin (no musculature exposed).

Fig. 5. Example of marks with no perforation through the skin; musculature is exposed via skin sloughing.

Examples of Type-A, Stage-I Sea Lamprey Marks on Lake Sturgeon

2a.	Skin is rough to touch, white and necrotic	• Skin around the mark is rough to the touch	A-I
2b.	Skin not rough to touch, some healing	• Healing is indicated by the presence of mucus covering the perforation	3

Fig. 6. Pit readily observed, no healing (<0.5 d post-sea lamprey detachment).

Fig. 7. White necrotic tissue around mark site, no healing (<0.5 d post-sea lamprey detachment).

Fig. 8. Skin around pit is rough to the touch, no healing (<0.5 d post-sea lamprey detachment).

Fig. 9. One barbel is absent, the three remaining barbels are damaged, no healing (<0.5 d post-sea lamprey detachment).

Examples of Type-A, Stage-II Sea Lamprey Marks on Lake Sturgeon

3a.	Muscle exposed, reddish membrane covering pit	• Healing evident; membrane over the mark • Skin is smooth to the touch • No re-pigmentation of the skin around attachment site	A-II
3b.	Muscle only slightly or not at all exposed, no reddish membrane, some re-pigmentation of skin around attachment site	• Considerable healing, and pit diameter small • Dark (dorsal attack) or white (ventral attack) pigmentation returning to the skin around the pit	4

Fig. 10. Reddish membrane covering the pit, skin is smooth to the touch, little healing (7 d post-sea lamprey detachment).

Fig. 11. Hemorrhaging around the pit site, little healing (7 d post-sea lamprey detachment).

Fig. 12. Pit is still present, but membrane has developed over musculature, little healing (7 d post-sea lamprey detachment).

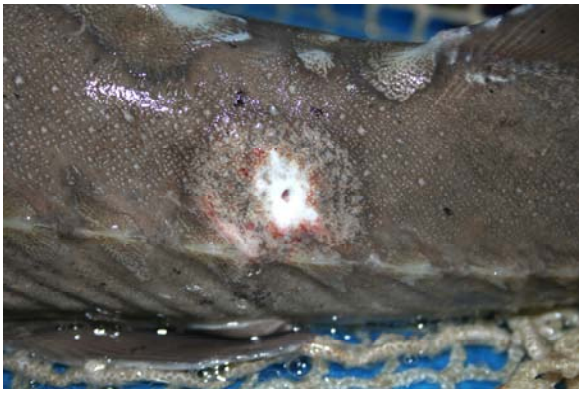


Fig. 13. Skin around pit site is smooth to the touch, no re-pigmentation, little healing (7 d post-sea lamprey detachment).

Examples of Type-A, Stage-III Sea Lamprey Marks on Lake Sturgeon

4a.	Pit present, but diminished; some re- pigmentation	• Healing of muscle has taken place • Noticeable return of skin pigmentation	A-III
4b.	No pit present; skin re-pigmented	• A completely healed Type-A mark • Skin completely re-pigmented	A-IV

Fig. 14. Musculature no longer exposed, considerable healing (same fish as in Fig. 12; 15 d post-sea lamprey detachment).

Fig. 15. Pit size diminished, no hemorrhaging around pit, considerable healing (30 d post-sea lamprey detachment).

Fig. 16. Some muscle exposed, considerable healing (14 d post-sea lamprey detachment).

Fig. 17. Muscle no longer exposed, dark re-pigmentation around margins of attachment site, considerable healing (34 d post-sea lamprey detachment).

Examples of Type-A, Stage-IV Sea Lamprey Marks on Lake Sturgeon

Fig. 18. Completely healed, re-pigmentation complete (124 d post-sea lamprey detachment).

Fig. 19. Completely healed, can still feel pit (128 d post-sea lamprey detachment).

Examples of Type-B, Stage-I Sea Lamprey Marks on Lake Sturgeon

5a.	Skin rough to the touch	• Skin around mark is rough to the touch	B-I
5b.	Skin not rough to the touch, some healing	• Limited signs of healing	6

Fig. 20. Abrasion, skin is rough to the touch, no healing (<0.5 d post-sea lamprey detachment).

Fig. 21. Abrasion, skin is rough to the touch, no healing (<0.5 d post-sea lamprey detachment).

Fig. 22. Abrasion, skin is rough to the touch, no healing (<0.5 d post-sea lamprey detachment).

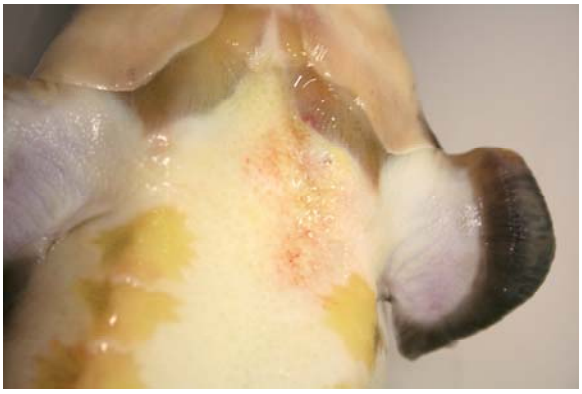


Fig. 23. Broken blood vessels, skin is rough to the touch, no healing (<0.5 d post-sea lamprey detachment).

Examples of Type-B, Stage-II Sea Lamprey Marks on Lake Sturgeon

6a.	Skin may or may not be broken	• Skin around mark is smooth to the touch • Some signs of healing, no re-pigmentation	B-II
6b.	Skin not broken	• Re-pigmentation around attachment site • Significant signs of healing	7

Fig. 24. Mucus indicates some healing, no re-pigmentation (8 d post-sea lamprey detachment).

Fig. 25. Skin smooth to the touch, no re-pigmentation, little healing (29 d post-sea lamprey detachment).

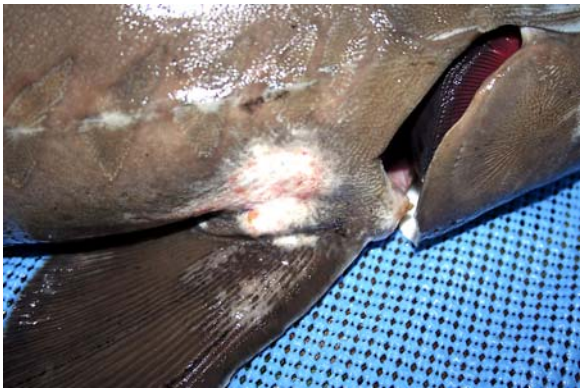


Fig. 26. Skin smooth to the touch, no re-pigmentation, little healing (14 d post-sea lamprey detachment).

Fig. 27. Skin smooth to the touch, some re-pigmentation, little healing (7 d post-sea lamprey detachment).

Examples of Type-B, Stage-III Sea Lamprey Marks on Lake Sturgeon

7a.	Skin smooth to the touch	• Re-pigmentation significant	
		• Considerable healing has taken place	B-III
7b.	Skin not rough to the touch, some healing	• Completely healed Type-B mark	B-IV

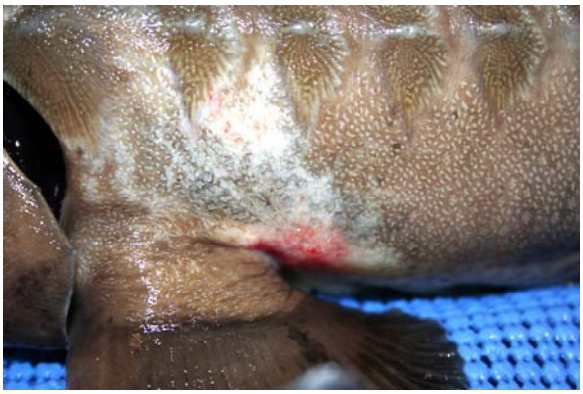


Fig. 28. Pigments returning, considerable healing (same fish as in Fig. 27; 15 d post-sea lamprey detachment).

Fig. 29. Broken blood vessels no longer visible, considerable healing (same fish as in Fig. 23; 31 d post-sea lamprey detachment).

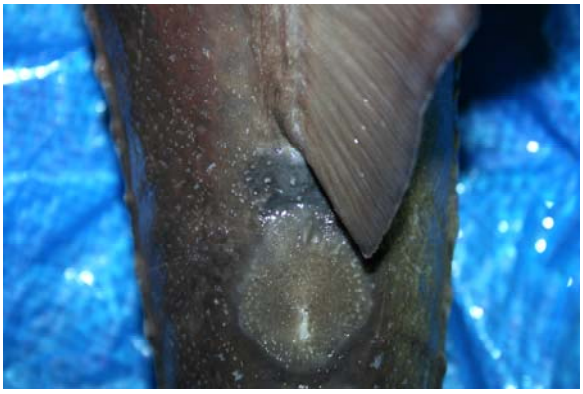


Fig. 30. Pigments returning, considerable healing (116 d post-sea lamprey detachment). Note: Pigmentation of the attachment site has darkened.

Fig. 31. Pigments returning, considerable healing (same fish as in Fig. 26; 63 d post-sea lamprey detachment). Note: Pigmentation of the attachment site has darkened.

Examples of Type-B, Stage-IV Sea Lamprey Marks on Lake Sturgeon

Fig. 32. Almost completely healed, re-pigmentation nearly complete (61 days post-sea lamprey detachment).

Fig. 33. Completely healed and re-pigmented (31 days post-sea lamprey detachment).

UNIQUE MARK HEALING CHARACTERISTICS ON LAKE STURGEON

One notable difference between most teleost fishes with scales and fishes that lack scales, such as lake sturgeon, is that Type-A marks on non-teleosts without scales often do not penetrate the musculature due to their thick skin and scutes. As a result, many Type-A marks on lake sturgeon that did not expose the musculature exhibited a healing process similar to Type-B marks. Regardless of mark type, the presence of darker pigmentation at the sea lamprey attachment site of dorsally located marks occurred during the final stages of healing for lake sturgeon. In a study of mark healing in yellowbelly rockcod (*Notothenia coriiceps*), an Antarctic species that often receives lesions to the integument from seal attacks, a similar phenomenon was observed after 60 d (Silva et al. 2005). This dark pigment is typical during the latter stages of mark healing and is caused by the presence of melanocytes in the epidermis. Silva et al. (2005) described the dark pigments originating at the margins of the lesion due to the replacement of melanocytes brought about by the sliding of the epidermis from the surrounding tissue, first from the epidermis and later (after 90 d) from the dermis. Silva et al. (2004) also described these changes from the original skin color at the injury site after 60 d and hypothesized that such change may minimize detection by predators and provide protection from ultraviolet radiation. The development of such pigmentation by lake sturgeon may have a genesis in avoiding detection by lamprey and may provide protection from ultraviolet radiation when sturgeon are spawning in rivers.

The lake sturgeon in our study exhibited more rapid rates of mark healing than described for lake trout. For example, the mean healing time from a Type-A, Stage-I mark to a Stage-II mark was 7 d for lake sturgeon maintained at 13.5ºC as compared to 13 d for lake trout maintained at 10ºC (King 1980). Furthermore, the mean healing time from a Type-A, Stage-I mark to a Stage-III mark was 20 d at 13.5ºC for lake sturgeon as compared to 94 d at 10ºC for lake trout. The relatively small sample sizes in King (1980) prevent comparison of healing rates for Type-B marks between lake trout and lake sturgeon. Although mark healing time has a tendency to decline at higher water temperatures, observations of sea lamprey marks on lake sturgeon in the field corroborate our observation of more rapid and more complete mark healing for lake sturgeon compared with other species (R. Elliott, personal communication).

Sea lamprey and lake sturgeon prefer different temperatures, which may limit contact between these two species during much of the year. For example, sea lamprey in Lake Huron were found primarily in water of 3°-5°C from April through June and moved to warmer (6°-15°C), shallower water during summer and early fall (Farmer et al. 1977). However, sea lamprey in our study appeared stressed at temperatures greater than 12°C. Sea lamprey typically occupy temperatures of 4°C in the deeper water of the Great Lakes during winter, although parasitic feeding activity decreases significantly during this period (Swink 1995). In contrast, the preferred temperature of lake sturgeon ranged from 12°-20°C between August and October (C. Goddard, Great Lakes Fishery Commission, 2100 Commonwealth Blvd., Suite 100, Ann Arbor, MI, 48105-1563, unpubl. data). Although the water temperature preferences of lake sturgeon and sea lamprey may coincide infrequently, lake temperature is uniform at about 12°C during fall turnover when sea lamprey feeding and host mortality is at its peak (Swink 1995). Furthermore, parasitic-phase sea lamprey often have minimal control over the temperature at which they feed (Swink 1993). Once a sea lamprey attaches to a host, it will either remain attached to the host to feed, regardless of

water temperature, or detach when the host enters an unfavorable temperature zone. In addition, sea lamprey are size-selective parasites, so larger lake sturgeon occurring out of their preferred temperature range may be more favorable hosts than smaller-bodied fish that are within their preferred temperature range (Swink 1991).

CLASSIFYING MULTIPLE AND SLIDING MARKS

Although some sea lampreys remain attached in a single location for the duration of an attack and produce marks that are straightforward to classify using this dichotomous key, others change their attachment location several times, sometimes sliding from one location to another. These types of attachments can produce complex marks that include both Type-A and -B marks, with some locations reaching healing stages before others. Hall and Elliott (1954) determined that the incidence of multiple scars increased for larger fish. The large body size of lake sturgeon make them more likely to receive multiple attachments by sea lamprey in comparison to smaller-bodied fish. Although our study involved the evaluation of the effects of a single sea lamprey attachment on lake sturgeon, we frequently observed the same sea lamprey attached at several locations on a lake sturgeon between observation periods.

If multiple marks are made by a single sea lamprey, a sliding mark will often connect the two marks and the marks will usually be in the same location on the host's body and at approximately the same stage of healing (Figs. 34, 35). However, if marks were made by more than one sea lamprey, no observable trace between the marks will be evident, the marks will typically be in different regions on the host's body, and the marks may be at different stages of healing.

Fig. 34. Example of a Type-B, Stage-II and a Type-B, Stage-III mark made by the same sea lamprey.

Fig. 35. Examples of Type-B, Stage-III marks made by the same sea lamprey. Note the multiple attachment sites located in the same region. Both marks were made by the same sea lamprey–only one mark should be recorded.

Reporting Protocol

We recommend following the Ebener et al. (2006) protocol for recording multiple and sliding sea lamprey marks on lake sturgeon. For such marks caused by a single sea lamprey, the following protocols are recommended:

- For multiple (non-sliding) marks, the most severe mark (i.e., Type A over Type B) should be recorded, with no more than one mark being recorded per individual lake sturgeon; if multiple marks are of the same type, the most recent (i.e., earliest stage) mark should be classified and recorded
- For sliding marks, the most recent attachment site should be recorded with no more than one mark being recorded per individual lake sturgeon; all sliding marks are classified as Type B

For multiple and sliding marks caused by two or more sea lampreys, the following protocol is recommended:

- The most severe mark (i.e., Type A over Type B) inflicted by each sea lamprey should be recorded, and, if the marks are of the same type, the mark in the earliest stage of healing should be recorded; for example, if Type-A, Stage-III and Type-B, Stage-II marks were determined to have been caused by the same sea lamprey (see preceding section) and a sliding Type-B, Stage-I mark was determined to have been caused by a second sea lamprey, two marks should be recorded for this lake sturgeon: Type A, Stage III and Type B, Stage I

RECORDING MARK SIZE

We recommend the Ebener et al. (2006) protocol for recording mark size. Of the two cohorts of parasitic sea lampreys in the Great Lakes at any one time, only marks made by the older cohort should be recorded. The oldest of the two cohorts would have metamorphosed earlier than the younger cohort, and the increased body size of this cohort increases its lethality. As a result, marking rates should be calculated only on marks made by the older cohort (Ebener et al. 2006).

Reporting Protocol

Marks made by the two cohorts of parasitic sea lampreys should be distinguished based on the diameter of their oral discs (mouths). The protocol is:

- Only marks with diameters that equal or exceed a quarter coin (about 20 mm) should be recorded for inclusion in standardized late-summer, fall, or spring marking data
- Marks less than 20 mm in diameter should be recorded in a database but should not be included in standardized marking statistics

The measurement of a sea lamprey mark should include the entire area made by the edge of the buccal funnel and should not be limited to the diameter of the pit (Fig. 36). Figs. 36 and 37 provide examples of large and small sea lamprey marks on lake sturgeon.

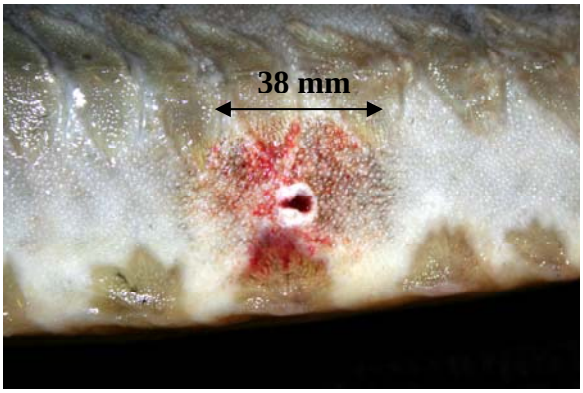


Fig. 36. Diameter of a large-sized mark measured across the whole attachment site.

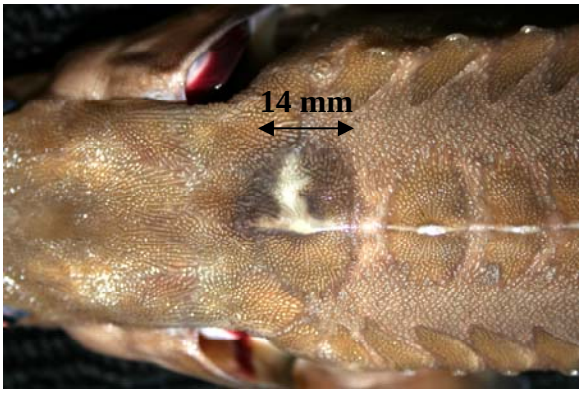


Fig. 37. Small mark (< 20 mm) not reported in marking statistics.

REFERENCES

Ebener, M.P., King, E.L., Jr., and Edsall, T.A. 2006. Application of a dichotomous key to the classification of sea lamprey marks on Great Lakes fish. Great Lakes Fish. Comm. Misc. Publ. 2006-02.

Farmer, G.J., Beamish, F.W.H., and Lett, P.F. 1977. Influence of water temperature on the growth rate of the landlocked sea lamprey (*Petromyzon marinus*) and the associated rate of host mortality. J. Fish. Res. Board. Can. **34**: 1373-1378.

Hall, A.E., Jr., and Elliott, O.E. 1954. Relationship of length of fish to incidence of sea lamprey scars on white suckers, *Catostomus commersoni*, in Lake Huron. Copeia 1954:73-74.

King, E.L., Jr. 1980. Classification of sea lamprey (*Petromyzon marinus*) attack marks on Great Lakes lake trout (*Salvelinus namaycush*). Can. J. Fish. Aquat. Sci. **37**: 1989-2006.

King, E.L., Jr., and Edsall, T.A. 1979. Illustrated field guide for the classification of sea lamprey attack marks on Great Lakes lake trout. Great Lakes Fish. Comm. Spec. Pub. 79-1.

Patrick, H.K. 2007. Host-size selection and lethality of sea lamprey on lake sturgeon. M. Sc. thesis, Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN.

Silva, J.R.M.C., Cooper, E.L., Sinhorini, I.L., Borges, J.C.S., Jensch, B.E., Jr., Porto-Neto, L.R., Hernandez-Blazquez, F.J., Vellutini, B.C., Pressinotti, L.N., and Pinto, F.A.C. 2005. Microscopical study of experimental mark healing in *Notothenia coriiceps* (Cabeçuda) at 0°C. Cell Tissue Res. **321**: 401-410.

Silva, J.R.M.C., Sinhorini, I.L., Jensch, B.E., Jr., Porto-Neto, L.R., Hernandez-Blazquez, F.J., Vellutini, B.C., Pressinotti, L.N., Pinto, F.A.C., Cooper, E.L., and Borges, J.C.S. 2004. Kinetics of induced mark repair at 0°C in the Antarctic fish (Cabeçuda) *Notothenia coriiceps*. Polar Biol. **27**: 458-464.

Swink, W.D. 1991. Host-size selection by parasitic sea lampreys. Trans. Am. Fish. Soc. **120**: 637-643.

Swink, W.D. 1993. Effect of water temperature on sea lamprey growth and lake trout survival. Trans. Am. Fish. Soc. **122**: 1161-1166.

Swink, W.D. 1995. Growth and survival of newly parasitic sea lampreys at representative winter temperatures. Trans. Am. Fish. Soc. **124**: 380-386.

ACKNOWLEDGEMENTS

Hatchery-reared lake sturgeon were provided by the U.S. Fish and Wildlife Service's National Fish Hatchery at Genoa, Wisconsin, the Wisconsin Department of Natural Resources, Wild Rose State Fish Hatchery, and the Michigan Department of Natural Resources, Wolf Lake State Fish Hatchery. Wild-caught lake sturgeon were provided by Purdy's Fishery of Point Edward, Ontario. Special thanks to Rob Elliott for guidance and to Bob Mollenhauer and Andrew Muir for their assistance in the lab. All photos were edited by Andrew Muir. This project was funded by the Great Lakes Fishery Commission.

MISCELLANEOUS PUBLICATIONS

February 1993	What's next? The prediction and management of exotic species in the Great Lakes (report of the 1991 workshop). E.L. Mills, J.H. Leach, C.L. Secor, and J.T. Carlton. 22 p.
August 1993	A survey of fish-community and habitat goals/objectives/targets and status in Great Lakes areas of concern. J.H. Hartig. 95 p.
August 1993	Toward integrating remedial-action and fishery-management planning in Great Lakes areas of concern. J.H. Hartig. 34 p
September 1994	Walleye-rehabilitation guidelines for the Great Lakes area. P.J. Colby, C.A. Lewis, R.L. Eshenroder, R.C. Haas, L.J. Hushak. 112 p.
April 1996	A lake trout restoration plan for Lake Superior. M.J. Hansen [ED.]. 34 p.
August 1998	A lake trout rehabilitation guide for Lake Huron. M.P. Ebener [ED.]. 48 p.
May 2003-01	A rehabilitation plan for walleye populations and habitats in Lake Superior. M.H. Hoff [ED.]. 22 p.
May 2003-02	A lake sturgeon rehabilitation plan for Lake Superior. N.A. Auer [ED.]. 28 p.
March 2006-01	A mid-decade review of progress under a “Strategic vision of the Great Lakes Fishery Commission for the first decade of the new millennium.” 45 p.
May 2006-02	Application of a dichotomous key to the classification of sea lamprey marks on Great Lakes fish. Ebener, M.P., E.L. King, Jr., T.A. Edsall. 22 p.
November 2007	A joint strategic plan for management of Great Lakes fisheries. Great Lakes Fishery Commission [ED.]. 28 p.

Cover photograph by Andrew Muir (Purdue University).