GREAT LAKES FISHERY COMMISSION

1986 Project Completion Report[1]

Scale, otolith, and growth characteristics of juvenile lake trout criteria for discriminating between indigenous and hatchery fish from the natural environment

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Original

RESEARCH COMPLETION REPORT

Scale, otolith, and growth characteristics of juvenile lake trout--criteria for discriminating between indigenous and hatchery fish from the natural environment[1]

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Note:

Original photographs used in figures are available for inspection at the offices of the Great Lakes Fishery Commission.

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ABSTRACT

Scale characteristics that can be used to identify and discriminate between juvenile indigenous lake trout and those of hatchery origin stocked as yearlings. These include differences in the spacing, width, and relative number of circuli; degree of fragmentation and coalescence of circuli in the checks, or breaks in the configurations of the circuli; and extent and relative location of primary checks (annuli and stocking checks). Generally, scales of fish of hatchery origin have a rather prominent, finely sculptured nucleus associated with a "stocking check" outside the first annulus.

Otoliths of hatchery lake trout stocked in the natural environment were atypical in shape and appearance. They contained a relatively opaque nucleus, or nodule, which appeared to be superimposed on the lateral side of a relatively translucent, crystalline, larger, otolithic mass. The symmetry of otolith growth appears to be disrupted at time of stocking.

Success of discrimination using scale characteristics is directly related to the experience of the interpreter, and was extremely high for experienced interpreters, approaching 100% for fish from the lake for which the criteria were developed. The overall average for samples from the Great Lakes (Huron, Michigan, and Superior) was 93%. Careful, detailed, and systematic examination of scales can partly compensate for lack of experience. Success of discrimination is inversely related to the number of types of hatchery stockings represented. The combined interpretation of scales and otoliths substantiates that unmarked fish from lakes Huron and Michigan appear to be indigenous, and are represented by the 1981 year class. However, some unmarked juvenile lake trout from Michigan appear to be of hatchery origin.

Known-age fish substantiate that growth rate of juvenile lake trout is very slow, and fish of hatchery origin are faster growing (33%) than are indigenous fish. Size of stocked hatchery fish at the second annulus was not significantly different than the size of indigenous juveniles one year older. Differences in scale characteristics and changes in growth rate may exist because the nursery environment, which is extremely deep (approximately 30 m), may not be reached immediately by some stocked fish. This accentuates the stocking check in the calcified tissue. Environmental conditions in this nursery habitat are appreciably different than those in the hatchery. These produce distinctly different growth patterns in the scales and otoliths of these two types of lake trout. It is hypothesized that juvenile lake trout must live in this profundal nursery refugium at temperatures below optimum for growth, and below the larger fish, to escape predation from the piscivorous pelagic adults living in shallower water.

Key words: lake trout, Salvelinus namaycush, scales, otoliths, growth rate, stocking check, stock discrimination, hatchery stocks, indigenous, culture, stocking, nursery habitat, nursery requirements, optimum temperature for growth, back-calculated size at scale age, age determination, known age, juveniles, yearlings,

Hatchery fish stocked in the natural environment have usually been identified by fin mutilation. However, "fin clipping" is not always successful, practical, or desirable. For example, it is difficult to culture some species artificially, so they must be stocked at a small size. This requires that very small fish be fin clipped, and this is usually not successful because it is difficult to remove small fins completely, the power of regeneration in small fish is very high, and the stress of handling and clipping can cause substantial mortality.

When hatchery fish are present and unmarked individuals are caught, it is difficult to know whether they are cultured fish that were either intentionally or inadvertently released unmarked, whether their fins were clipped and have subsequently regenerated, or whether in some cases they might represent important signs of natural recruitment.

In recent years, the Great Lakes Fishery Commission has received an increasing number of reports that juvenile unmarked lake trout were appearing in catches from lakes Huron and Michigan. It has not been known whether they were hatchery fish that were released inadvertently unmarked, or indigenous recruits (R. Eschenroder, Great Lakes Fishery Commission, Ann Arbor, Michigan; personal communication).

A technique was needed to determine the origin of these individuals. Even very sophisticated procedures such as electrophoresis might not successfully resolve their identity because if the unmarked fish were the progeny of hatchery stock, there may not have been adequate isolation to effect electrophoretic differences.

Calcified structures that are used for routine age determination contain a very specific growth record (Casselman 1978). It was decided to examine growth recorded in scales and otoliths to see if these might be used to distinguish between native lake trout and those of hatchery origin living in the natural environment. These might provide relatively simple techniques that could be used by fisheries managers. Furthermore, Cable (1956) had already reported that scales of hatchery lake trout stocked in Lake Michigan had a "0" check, which she used to ascertain if fish were of hatchery or native origin.

The purpose of this study was (1) to develop specific criteria, using scales and otoliths of juvenile lake trout from the natural environment but of known origin, (2) to test and refine these criteria to see if they could be used to differentiate between hatchery and indigenous fish from other environments, and (3) to apply the criteria to samples of unmarked juvenile lake trout from lakes Huron and Michigan to determine if they were indigenous fish, signifying natural recruitment.

MATERIALS AND METHODS

To develop the criteria, juvenile lake trout were used from Johnson Lake (45° 16' lat., 78° 37' long.), a deep, 150-hectare, oligotrophic lake in the Haliburton Highlands of Ontario. The lake contained native lake trout, but had been stocked in May 1981 with yearling hatchery fish (OMNR Lake Manitou stock) that had been marked with a right pectoral fin clip. Both hatchery and indigenous juvenile lake trout were collected from 1981 to 1983 in deep water sets (30-35 m) of fine mesh gill nets. The marked hatchery fish were of known age and were in their second and third calendar years when collected. The native lake trout were unmarked and distinctly different in body form and colouration.

Total length was measured, and scales and otoliths were removed from fresh or frozen and thawed fish. The structures were air-dried until subsequently processed. Scales were removed from a key scale sample area, midway along the trunk on both the anterior-posterior and dorsal-ventral axes.

In the laboratory, scales were placed on glass slides, then immersed in 80% ethyl alcohol, covered with a cover slip, and photographed at 76x magnification on a modified Magnaprint Reader (Model PE-1A by Eastman Kodak, Rochester, New York). At least three non-regenerated scales were printed for each fish. Whole otoliths were immersed in 80% alcohol in a depression slide and were photographed at 38x using transmitted light. The otoliths were then dried, embedded in Araldite (Ciba-Geigy Canada Ltd., Dorval, Quebec), and thin-sectioned transversely through the origin with a low-speed Isomet saw (Buehler Ltd., Evanston, Illinois). The sections were 200 to 300 um thick, and were examined under a dissecting microscope at low power (approximately 25x).

To build the distinguishing criteria, structures were examined from equal numbers (approximately 24) of marked (fin clipped--hatchery) and unmarked (not fin clipped--indigenous) lake trout. The checks, or breaks, in the configuration of the circuli on the scales were ranked by extent and location. The anterior radius of each primary check (considered to be associated with annuli or stocking), as well as the total anterior scale radius, were measured from the focus along the extreme anterior axis. Measurements were made with a digitizer interfaced with an IBM-PC microcomputer. For each fish the radii of at least three scales were averaged. Translucent zones of the otoliths were counted, and general morphology of the otolith was categorized.

To test and refine the criteria, additional lake trout samples were used from Johnson Lake, as well as from lakes Huron, Superior, and Michigan. Great Lakes lake trout were acquired and supplied by R. Eschenroder of the Great Lakes Fishery Commission. These samples were as follows: (1) Johnson Lake, unmarked, n = 5, TL = 21.2 ± 2.12 cm ($\bar{X}$ ± 95% Confidence Interval); marked (RPT), n = 5, 1980 year class, 21.3 ± 3.09 cm; collected by experimental gill nets May to July 1981, 1982, and 1983. (2) Lake Huron, unmarked, n = 5, 19.5 ± 3.15 cm; marked (LPV), n = 8, 1982 year class, 17.0 ± 1.22 cm; collected by bottom trawl June to October 1983 in the Rockport area, north of Alpena, Michigan. (3) Lake Superior, unmarked, n = 5, 19.0 ± 1.34 cm; marked (Ad), n = 11, 1982 year class, 16.6 ± 0.84 cm; and (RPV), n = 9, 1981 year class, 20.04 ± 0.90 cm, collected by gill nets September 1983 in the vicinity of Cat and Basswood islands, Wisconsin; hatchery fish, n = 6, 1983 year class, 11.4 ± 2.25 cm, removed September 1983 from Bayfield Hatchery. (4) Lake Michigan, unmarked, n = 16, 32.3 ± 6.0 cm; marked with 6 different fin clips, n = 43, (Ad), n = 7, 1982 year class, 21.8 ± 1.49 cm, collected by trawl and gill net August and September 1983, in the vicinity of Grand Traverse Bay, Michigan.

Great Lakes fish were frozen, and were processed in a manner similar to those from Johnson Lake. All fins were examined carefully to detect any indication of anomalous conditions that might indicate previous clipping, based on length, area, or abnormal regeneration of the fin rays. All marked hatchery fish referred to in this study were stocked in their second calendar year in spring, usually early May, as yearlings.

During the Ontario Ministry of Natural Resources Age and Growth

Workshop, 1985, 21 different scale interpreters helped test the effect of experience on differentiating between hatchery and indigenous fish, using scale criteria. These people routinely interpret age of fish from scales and other calcified structures. Some had no experience with scales of lake trout. The experience of those who worked with the species was measured by the number of lake trout scale samples that they interpret annually. All interpreters were given a list of the contrasting criteria that had been developed and a typical illustration for each group (presented below), and were asked to assign an identity to each fish, based on photographs of the scales. The identification was based on only one scale image for each fish; however, in some cases fish were represented more than once by different scales, and several scale images were duplicated. No data were supplied although samples were grouped according to lake of origin. A confidence ranking (1--least, to 9--most) was assigned to each interpretation.

Body-scale relations were constructed to examine differences in growth rate. A combined relation was used, and back-calculation was performed using standard procedures (Whitney and Carlander 1956). Instantaneous growth rates were calculated using natural logarithms of body lengths determined from back-calculated size at scale age, expressed as percent change in body length per day. To interpret growth data, environmental conditions of the nursery ground were considered, using data collected on mid-summer vertical distribution of lake trout in Wildcat Lake, small inland lake in the Haliburton Highlands of Ontario. Vertical distribution was determined in a study using monofilament gill nets 1/2 to 5 1/2 inch stretch measurement, set on bottom at 10-meter depth intervals throughout the entire depth of the lake.

RESULTS AND DISCUSSION

Scale Characteristics

Scale criteria

The extent and relative location of checks on the scales were interpreted and compared and contrasted for juvenile lake trout from Johnson Lake. Marked and unmarked lake trout showed some distinct differences. Basic differences are summarized in Table 1, and are illustrated with typical examples in Fig. 1. Although spacing, width, and relative number of circuli, as well as degree of fragmentation and coalescence of the circuli in the check, were useful, the criteria most frequently used for separating these two groups involved the extent and relative location of the first two primary checks. Very generally, scales of marked fish of hatchery origin contained a nucleus that was composed of relatively numerous, narrow circuli delineated by a prominent check or break in the scale pattern, which was usually accentuated by more widely spaced circuli outside this check. This often gave the appearance that the nucleus contained a more finely sculptured miniature scale superimposed on the origin with thicker, more widely spaced circuli outside it. Assuming that spacing of circuli indicates growth rate, then the change in spacing outside this nucleus indicates a decrease or cessation in growth rate followed by a prominent increase in growth rate. The formation of this check and a rather abrupt change in spacing of the circuli was comfirmed by comparing scale samples of hatchery fish taken at time of stocking with those from fish recaptured immediately after stocking and later. The most prominent check on scales of planted hatchery juvenile lake trout is the "stocking check", which is delineated by more widely spaced circuli. The first annulus, which forms in the hatchery, is usually contained in a less prominent check located just inside the stocking check. No such abrupt change was apparent on scales of native fish.

Discrimination using scale criteria

Experience would be expected to influence the ability to recognize checks and the success of the identification and discrimination process. For the Great Lakes samples, there was a direct correlation between the experience of the interpreter and percent identified correctly (Fig. 2). However, this was not the case for Johnson Lake fish because a high percentage of the interpreters who had no experience with lake trout scales were able to use these criteria to identify correctly the origin of all the Johnson Lake fish.

Correct identification differed between inexperienced and experienced interpreters by 22% (78 and 100%) for the Johnson Lake samples and by 26% (58 and 84%) for the Lake Michigan samples (Table 2). On the average, when using these scale criteria, inexperienced interpreters correctly assigned membership 66% of the time, whereas experienced interpreters were successful 93% of the time.

Although experience is important, a systematic, rigorous, and careful interpretation of the breaks, width, and spacing of the circuli can partially compensate for lack of experience. Inexperienced interpreters who were instructed to conduct a thorough inspection that involved actually marking on a photographic print each break or change in the configuration of the circuli with a coloured marker scored 8 to 10% higher than those who were simply given the criteria and allowed to proceed. Several inexperienced interpreters were given the same type of test on different samples, approximately two months later. Their discrimination improved an average of 12%, confirming that ability to differentiate between these two groups improves with experience.

Although numerous factors affect the discrimination, checks on scales of fish of hatchery origin are generally somewhat more variable and difficult to categorize. The criteria vary, depending upon specific hatchery conditions. For experienced interpreters, correct identification of fish in a sample was inversely related to the number of different types of marks (fin clips) on the hatchery fish. These marks indicate different hatchery lots and probably different growth conditions. These variables were related as follows:

$$Y_{\%\text{ correct ID}} = 104.9 - 7.09X_{\text{No. of different types of fin clips}}$$

$N = 4 \qquad r = 0.97^{**}$

In contrast, scale characteristics of native lake trout were usually less variable. The annuli were, however, relatively indistinct and difficult to locate, circuli were uniformly spaced, and since scales of indigenous fish lacked the prominent nucleus that usually appeared on scales of hatchery fish, identification was assigned to some extent by default (Fig. 1).

Scales of both marked and unmarked lake trout from Johnson Lake were easily recognized (e.g., Fig. 3), and the results were highly accurate (Table 2). However, this might be expected because the criteria were built specifically using these two stocks of fish. When distinguishing between these fish, the confidence rankings were usually extremely high ($\bar{x}$ = 8.2). Spacing of the primary checks was considered to be the best single criterion.

A cursory examination of samples from the Great Lakes indicated that similar criteria would apply. In the Lake Huron sample (e.g., Fig. 4) characteristics in scales of marked lake trout were less distinct than those for lake trout from Johnson Lake. This is as expected, because the hatchery fish were of different origins than those of Johnson Lake, and no doubt had slightly different environmental and growth histories, even though they were reared for approximately the same length of time and were stocked at the same time of year. However, scale characteristics of unmarked fish were very similar to those of Johnson Lake. The criteria applied equally well to juvenile lake trout from Lake Huron, which were accurately separated, especially by experienced interpreters (96%) (Table 2).

It was more difficult to interpret scales from Lake Superior fish (e.g., Fig. 5), no doubt partly because the group of marked fish was comprised of two different lots, probably reflecting slightly different hatchery growth and stocking conditions. Also, the unmarked fish had a characteristic first annulus and nucleus which was composed of thin, narrowly spaced circuli, giving an overall impression somewhat similar to that of hatchery fish (Fig. 5). However, this nucleus was much smaller than the typical nucleus on scales of hatchery fish, indicating relatively slow growth in the first year. Even though the second annulus was quite distinct and distant from the first annulus, this pattern about the nucleus in some of the unmarked indigenous fish was sometimes misleading and was probably misinterpreted as hatchery growth in some indigenous fish.

The Lake Michigan scales (e.g., Fig. 6) produced the poorest results and the lowest confidence rankings ($\bar{x}$ = 5.8). There are several possible explanations. It was probably because the sample of marked fish contained several different types of hatchery plants, representing different hatchery treatments and stocking conditions (three were used in the test). Nevertheless, as with marked fish from other lakes, when the typical hatchery nucleus was present, it was quite distinct (Fig. 6). Unmarked fish in the Lake Michigan sample were relatively poorly identified. Several of the samples were consistently classified incorrectly by the 16 interpreters who tested the method (e.g., correct identification of some fish was as low as 25%). It was obvious on close examination that the characteristics of some of these scales were more indicative of hatchery than of indigenous fish. From the scale examination, it was suspected that some unmarked fish were actually of hatchery origin.

Otolith Characteristics

Otolith criteria

Otolith differences were more conspicuous and simpler to detect than those of scales. From preliminary examination at low magnification, it was obvious that otoliths of marked juvenile fish used in this study were often atypical in shape and appearance. Very generally, the otoliths of juvenile fish of hatchery origin contained a relatively opaque nucleus, or nodule, that appeared to be superimposed on the lateral side of a relatively translucent, even crystalline, larger otolithic mass. More recent growth within the otolith appeared to be extremely translucent and strongly allometric. In contrast, otoliths of unmarked native fish were always more uniformly opaque and appeared more symmetrical.

Although these differences were readily visible in whole otoliths viewed at low magnification in incident light (Fig. 7), they were extremely obvious when transverse thin sections through the origin were removed and examined under slightly higher magnification (Fig. 8). This change in otolith growth appeared to occur after stocking, because growth of the otolith of hatchery fish prior to stocking appeared normal at the sub-macroscopic level.

Discrimination using otolith criteria

Approximately 70% of the marked lake trout had otoliths with this anomalous type of growth; however, the frequency of occurrence varied somewhat between lakes (Table 2). Not all lake trout of hatchery origin had this anomalous type of otolith. Otoliths from unmarked juvenile lake trout were normal in all samples except those from Lake Michigan. Indeed, as indicated later, some of the exceptions in the Lake Michigan sample actually may actually have been caused by unmarked hatchery fish. Therefore, the otolith criteria may be more reliable than results that include the Lake Michigan fish indicate. On the average, otolith characteristics correctly assigned the identity of 79% of the fish. The otolith criteria were obvious enough that experience did not improve discrimination.

Discrimination Using Combined Scale and Otolith Characteristics

When results of the scale and otolith interpretations for the same fish were combined, it was apparent that all unmarked juvenile lake trout in the samples from all lakes except Lake Michigan had characteristics consistent with indigenous fish. However, some unmarked lake trout in the Michigan sample had characteristics in both the scales and otoliths that could be associated only with stocked, hatchery fish (e.g., Fig. 9). Indeed, only 63% of the unmarked Lake Michigan lake trout had characteristics typical of indigenous fish.

No ready explanation can be given for the relatively high percentage of unmarked Lake Michigan fish that appeared to be of questionable origin. However, it is apparent from growth data presented later that Lake Michigan fish are fast growing, and if fins of hatchery fish were only partially clipped, they could easily have regenerated. Special effort was made during the initial examination to examine the fins carefully to avoid misidentification. In fact, some marked Lake Michigan fish had clipped fins that were virtually regenerated (90% present). It is also possible that some fish stocked as fin clipped hatchery fish might have been inadvertently released unclipped. However, the proportions in this case seem to be extremely high. Examination of routine clipping of stocked fish indicated that typically a small percentage (3%) of hatchery fish may be stocked virtually unclipped (Table 3), but in some cases a considerable proportion (15% in these examples) may be only partially clipped. If growth were extremely rapid, as is the case in Lake Michigan lake trout, the fins could easily regenerate, obscuring the true origin of the fish.

The results of the interpretation of scales and otoliths of unmarked fish provide strong circumstantial evidence that natural recruitment is occurring in lake trout stocks in the parts of lakes Huron and Michigan where these samples were collected. Since native lake trout have not been seen for many years in the sectors of the lakes from which these samples were taken, indigenous juvenile lake trout, progeny of hatchery stocks, now appear to be present. In

Lake Huron these fish would be of the 1981 year class. In Lake Michigan there appear to be several year classes, including 1981.

Growth Characteristics and Environmental Conditions in the Nursery Habitat of Juvenile Lake Trout

This detailed interpretation of checks on scales of juvenile lake trout provided the opportunity to document growth differences between marked and unmarked juvenile lake trout and to validate the interpretation using the hatchery fish, which were of known-age. The body-scale relations over these size ranges were linear (Table 4, Fig. 10), and back-calculated size at scale age was used to provide corroboratory evidence that the checks interpreted as annuli and stocking checks corresponded to the previous sizes of the stocked fish when these respective checks formed. Total body length at time of stocking for lake trout from Johnson Lake (11.5 ± 0.24 cm) was not significantly different (within 4%) from the body size estimated by back-calculating to the stocking check on scales of fish recaptured later (12.9 ± 0.95 cm, Table 5).

Indeed, back-calculated lengths at age showed excellent agreement with empirical lengths of fish collected at corresponding ages. There was no significant difference between these values (Table 5) and empirical lengths for Johnson Lake, June, 3rd calendar year, 21.0 ± 3.09 cm; Lake Huron, August and October, 2nd calendar year, 17.0 ± 1.22 cm; Lake Superior, September, 2nd calendar year, 16.6 ± 0.84 cm; Lake Michigan, September, 2nd calendar year, 21.8 ± 1.49 cm.

It is apparent from average values that native juvenile lake trout are slower growing than are stocked hatchery fish. Size of stocked hatchery fish at the second annulus was not appreciably different from the size of indigenous fish living in the same environment, but one year older at the third annulus (Table 5). Lake trout in the natural environment, regardless of their origin, grow very slowly during their second and third years. This is confirmed by two lots of hatchery fish taken from Lake Superior, one at the end of the second and the other at the end of the third year. Their lengths differed by only 3.8 cm (16.6 ± 0.84 cm as compared with 20.4 ± 0.90 cm). The unmarked fish showed similar results, which are typical for the species (Eschmeyer 1956), with a difference of only 5.1 cm between the second annulus (15.2 cm) and the third annulus (20.3 cm).

The average daily specific linear growth rate for indigenous lake trout was 0.623 in the first calendar year, 0.123 in the second year, and 0.079 in the third year. Instantaneous growth rates for hatchery fish stocked as yearlings were greater: first year of life in the hatchery 0.647, second year up to time of stocking 0.196, from stocking to end of the second year 0.150, and average for the second year 0.163, or approximately 33% greater than indigenous lake trout.

Midsummer vertical distribution provides a plausible explanation for such low growth rates. Fingerling and juvenile lake trout up to approximately 25 cm TL live in extremely deep water. These juvenile fish are usually found at 30 m, however their depth distribution ranged from 25 to 35 m, with some individuals found in deeper water (Fig. 11). It appears that juvenile lake trout live in this profundal nursery habitat until they are sub-adult, when they move into shallower water and live above the adults. There is a significant increase in growth rate when these juvenile fish change habitat and move shallower, usually in the fourth or fifth calendar year. There is a direct relationship between size (length) of subadult and adult lake trout and their midsummer vertical distribution (Fig. 11).

This profundal existence directly affects growth rate, and no doubt partially explains some of the differences observed in the number, spacing, and continuity of the circuli on the scales of hatchery and indigenous lake trout. Differences in growth and scale characteristics would be expected when comparing hatchery fish living in raceways or rearing ponds (and fed *ad libitum*) at temperatures close to the optimum for linear growth--10 C (O'Connor et al. 1981) and grow rapidly as compared with native fish foraging naturally and living in the profundal portion of the lake at low temperatures (approximately 4 C), well below the optimum. It is hypothesized that this deepwater nursery habitat, which is typical for the young of the species (Eschmeyer 1956), is essential if they are to escape predation, which would undoubtedly occur if they lived in shallow water among or above the larger, older pelagic piscivorous lake trout. Although juveniles are less vulnerable to predation in this deepwater refuge, they must live in conditions that appear to be suboptimal for growth.

Numerous factors affect the type and conspicuousness of the stocking check that appears on scales. This check often is more prominent than the first annulus that precedes it, which forms in the hatchery. The conspicuousness of the stocking check provides a measure of the disruption in growth that occurs at time of stocking. Intensive netting and electrofishing studies immediately after hatchery fish have been stocked indicate that stocked juvenile lake trout can remain in shallow water in the littoral zone (<2 m) for several weeks (up to 8) before descending to the profundal nursery environment. Young lake trout, especially juveniles, are not usually found in such shallow water, especially juveniles (Eschmeyer 1956; Peck 1982). If stocked yearling lake trout remain in shallow water for an extended period of time after stocking in spring, they would not only be vulnerable to predation by large lake trout that are actively feeding in the shallows at that time of year, but would also live at extremely high temperatures, well above the optimum. This would greatly alter growth of the calcified tissue. Hatchery growth conditions and stocking practices can have a very specific affect on growth of calcified tissue and its ultimate appearance.

CONCLUSIONS

Criteria have been developed, using scales and otoliths, that permit reasonable success in distinguishing between hatchery and indigenous lake trout. Although the criteria are rather specific, their recognition improves with experience, and the success of the discrimination is increased by any factor that accentuates the change in growth effecting the stocking check. The method is most successfully performed when the criteria are specifically constructed for a particular stock of hatchery fish, and consider their unique hatchery growth and stocking conditions.

The success of the discrimination is inversely related to the number of types of growth histories considered. Using these basic criteria, it would be possible to build more specific scale and otolith characteristics based more directly on specific growth conditions in the hatchery and associated with subsequent stocking. Scales and otoliths from unmarked lake trout from lakes Huron and Michigan contain characteristics that are typical of indigenous fish. Although the evidence is circumstantial, it indicates that indigenous juvenile lake trout may occur in these two lakes in sectors where native lake trout appear to have been become extinct. Reproduction of planted lake trout has already been reported for Lake Michigan (Wagner 1981), and appears also to have occurred in Lake Huron.

Current culture and stocking practices produce very distinct characteristics in the scales and otoliths of artifically reared lake trout. These result because hatchery conditions for lake trout are distinctly different from conditions in the natural nursery habitat. Also, because of current stocking practices, recently stocked juvenile fish may spend considerable time in shallow water before moving to the deep water nursery habitat. This could interfere with normal growth and accentuate the "stocking check" in scales and otoliths, and produce characteristics that are considerably more prominent than some of the unique growth differences that have already been associated with hatchery culture of other species such as lake whitefish (Van Oosten 1961) and walleye (Serns 1981).

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Table 1. Criteria for differentiating between marked and unmarked lake trout using characteristics of the configurations of the circuli on scales. Criteria were developed from marked (fin-clipped) juvenile fish of hatchery origin and unmarked indigenous (by colour, form, and electrophoresis) lake trout from the natural environment of Johnson Lake, Ontario.

	Marked	Unmarked
1	Thin circuli inside the first two checks	Thick circuli inside the first two checks
2	Narrowly spaced circuli inside the first prominent check	Moderately widely spaced circuli inside the first prominent check
3	Numerous circuli inside the first two checks	Few circuli inside the first two checks
4	Circuli more fragmented in the lateral portion of the first check	Circuli less fragmented in the lateral portion of the first check
5	Numerous circuli cross the posterior field	Few circuli cross the posterior field
6	First two checks usually very close together (sometimes coalesce in lateral) and distal from the focus; first and third checks are annuli, second check is probably a stocking check (SC)	First two checks uniformly spaced, and are annuli; second check is an annulus
7	Often scales (e.g., Johnson Lake) are of comparable size at the second annulus	Often scales (e.g., Johnson Lake) are of comparable size at the third annulus

Table 2. Percent of the samples from the four sources identified correctly using the criteria for scale characteristics associated with marked and unmarked juvenile lake trout. The percent of the scale samples identified correctly by inexperienced (have never examined lake trout scales) and experienced (routinely interpret lake trout scales) interpreters. Percent of the otoliths of marked and unmarked juvenile lake trout that are classified as normal and abnormal according to opacity and translucency of the otolith. Percent of the unmarked lake trout from the four sources that by both scale and otolith characteristics are considered to be indigenous.

		Scale check characteristics							Otolith opacity and translucency					
		Marked		Unmarked			Interpreter experience		Marked		Unmarked			
Source	N	N	% identified correctly	N	% identified correctly	Average % identified correctly	Inexperienced % identified correctly	Experienced % identified correctly	N	% abnormal	N	% normal	Average % identified correctly	% unmarked assumed to be indigenous
Johnson Lake	11	4	94	7	88	91	78	100	6	66	5	100	83	100
Lake Huron	13	4	75	6	62	69	61	96	6	83	5	100	92	100
Lake Superior	25	17	67	8	78	73	67	90	16	63	4	100	82	100
Lake Michigan	60	16	67	11	56	62	58	84	43	60	16	56	58	63
Total	109	41		32					71		30			
Average			76		71	74	66	93		68		89	79	91

Table 3. Frequency of occurrence of the percent of right pectoral fin that was present, classified on the basis of length and area, for two different lots of 200 lake trout each randomly subsampled from yearling fish stocked in lake trout lakes in the Haliburton Highlands of Ontario, May 1981.

Classification of future recognition	% of right pectoral fin present										
	100	90	80	70	60	50	40	30	20	10	0
	Not recognizable			Questionable				Recognizable			
% frequency of occurrence	2	1	0	1	6	4	2	0	3	16	66
% accumulated occurrence	2	3	3	4	10	14	16	16	19	25	101

Table 4. Body-scale relations for the juvenile lake trout from Johnson Lake and lakes Huron, Superior, and Michigan used in the study.

Source	Equation	N	r	sign.
Johnson Lake	Y = 5.67 + 21.14X	10	0.98	**
Lake Huron	Y = 0.29 + 26.80X	11	0.99	**
Lake Superior	Y = 4.26 + 21.07X	30	0.95	**
Lake Michigan	Y = 2.79 + 27.05X	60	0.95	**
Combined	Y = 0.52 + 28.46X	111	0.98	**
Average	Y = 3.25 + 24.02X			

Table 5. Average back-calculated body length (cm) at age for marked and unmarked juvenile lake trout from the four sources used in the comparison. Average lengths were estimated from three scales for each fish at each annulus, and, for the marked fish, at the stocking check.

	First annulus						Stocking check			Second annulus						Third annulus		
	Marked[a]			Unmarked						Marked			Unmarked			Unmarked		
Source	N	$\bar{x}$	95% CI	N	$\bar{x}$	95% CI	N	$\bar{x}$	95% CI	N	$\bar{x}$	95% CI	N	$\bar{x}$	95% CI	N	$\bar{x}$	95% CI
Johnson Lake	4	10.3	1.42				4	12.0	0.95	4	20.4	0.52						
				7	9.0	0.44							7	13.3	0.80	7	19.5	1.13
Lake Huron	4	8.4	1.12				4	10.5	1.98	4	17.1	1.08						
				6	9.6	1.00							6	15.7	1.05	6	20.6	2.25
Lake Superior	17	10.9	1.04				17	13.6	1.34	17	18.2	1.30						
				7	9.1	0.36							7	15.5	2.13	7	19.4	1.47
Lake Michigan	18	12.7	0.49				18	15.4	0.48	18	21.2	1.12						
				9	11.2	0.92							9	16.3	1.02	9	21.5	2.13
Average		10.6						12.9			19.2							
					9.7									15.2			20.3	

[a]First annulus on scales of marked fish forms in late winter in the hatchery.

CAPTIONS

Figure 1. Scale characteristics associated with marked (hatchery) and unmarked (indigenous) juvenile lake trout from Johnson Lake. Scales are from a marked lake trout caught June 16, 1982, 20.2 cm TL, 68.2 g, 1980 year class; and an unmarked lake trout, having form and colouration of a native fish, caught June 16, 1982, 20.4 cm TL, 63.0 g, 1979 year class. All scales are illustrated as positives (76x), with anterior up and dorsal side right. Annuli and stocking check (SC) are indicated. On the scale of the marked lake trout small arrows indicate an annulus, and large arrow indicates the stocking check. On the scale from the unmarked lake trout large arrows indicate annuli. Back-calculated body size: for marked fish, first annulus--10.4 cm TL, SC--11.7; for unmarked fish, first annulus--9.0 cm TL, second annulus--14.4 cm TL.

Figure 2. Relation between percent of the scale samples from four sources that were identified correctly according to origin, and the experience of the interpreter, as indicated by the number of lake trout scale samples that were examined per year. The number of interpreters examining the samples is indicated by N. Where a correlation exists, the trend is indicated by the regression line and equation.

Figure 3. Typical scales of juvenile lake trout from Johnson Lake. Arrows are the same as in Fig. 1. Scales from marked lake trout (1980 year class) (A) caught June 16, 1982, 20.6 cm TL, 63.2 g, identified correctly--95%; (B) caught June 16, 1982, 20.6 cm TL, 68.2 g, identified correctly--100%. Scales from unmarked lake trout having form and colouration of native fish (C) caught June 16, 1982, 20.4 cm TL, 63.0 g, 1979 year class,

identified correctly--95%; (D) caught June 16, 1982, 19.9 cm TL, 66.1 g, 1979 year class, identified correctly--100%. Scales are illustrated as positives (76x).

Figure 4. Typical scales of juvenile lake trout from Lake Huron. Arrows are the same as in Fig. 1. Scales from marked fin-clipped lake trout (1982 year class) (A) caught August 24, 1983, 16.9 cm TL, 39.0 g, identified correctly--90%; (B) caught October 26, 1983, 18.5 cm TL, 56.9 g, identified correctly--95%. Scales from unmarked lake trout having form and colouration of native fish (C) caught October 26, 1983, 23.1 cm TL, 115.1 g, 1981 year class, identified correctly--75%; (D) caught July 20, 1983, 20.0 cm TL, 80.3 g, 1981 year class, identified correctly--86%. Scales are illustrated as positives (76x).

Figure 5. Typical scales of juvenile lake trout from Lake Superior. Arrows are the same as in Fig. 1. Scales from marked lake trout (1982 year class) (A) caught September 9, 1983, 16.3 cm TL, 30.8 g, identified correctly--88%; (B) caught September 9, 1983, 19.5 cm TL, 53.3 g, identified correctly--88%. Scales from unmarked lake trout having form and colouration of native fish (C) caught September 13, 1983, 21.1 cm TL, 86.3 g, 1981 year class, identified correctly--94%; (D) caught September 13, 1983, 19.3 cm TL, 59.0 g, 1981 year class, identified correctly--75%. Scales are illustrated as positives (76x).

Figure 6. Typical scales of juvenile lake trout from Lake Michigan. Arrows are the same as in Fig. 1. Central portion of scales from marked lake trout (1979 year class) (A) caught September 1983, 48.4 cm TL, 1108.1 g, identified correctly--100%; (B) caught September 1983, 49.5 cm TL, 1122.5 g, identified

correctly--100%. Scales from unmarked lake trout having form and colouration similar to native fish (C) caught September 1983, 20.2 cm TL, 78.7 g, 1981 year class, identified correctly--100%; (D) caught September 15, 1983, 20.6 cm TL, 73.1 g, 1981 year class, identified correctly--60%. Scales are illustrated as positives (76x).

Figure 7. Typical whole otoliths of juvenile lake trout from Lake Huron. Otoliths from marked lake trout (A) caught October 26, 1983, 16.4 cm TL, 37.1 g (left otolith); (B) caught August 24, 1983, 14.2 cm TL, 24.0 g (right otolith). Arrows indicate opaque nucleus (nodule on the lateral surface) surrounded by extremely translucent crystalline material. Left otoliths from unmarked lake trout (C) caught October 26, 1983, 23.1 cm TL, 115.1 g; (D) caught August 24, 1983, 18.8 cm TL, 62.2 g. Otoliths of unmarked lake trout are uniformly opaque throughout. Viewed in incident light (38x).

Figure 8. Transverse sections of typical otoliths of juvenile lake trout from Lake Huron. Left otoliths from marked lake trout (1982 year class) (A) caught October 26, 1983, 18.5 cm TL, 56.9 g (74x, thickness 190 um); (B) caught August 24, 1983, 14.2 cm TL, 24.0 g (78x, thickness 210 um). Arrows indicate opaque nodule on the lateral surface. Left otoliths from unmarked lake trout (C) caught October 26, 1983, 23.1 cm TL, 115.1 g, 1982 year class, (74x, thickness 210 um); (D) caught August 24, 1983, 18.8 cm TL, 62.2 g, 1982 year class, (78x, thickness 210 um). Viewed in transmitted light.

Figure 9. Scale and otolith section from an "unmarked" lake trout from Lake Michigan caught September 16, 1983, 34.5 cm TL, 499.5 g, 1981 year class. Central portion of the scale (A)

indicates typical pattern of a marked fish; identified correctly (as an unmarked fish)--25% (76x). Small arrow indicates annulus, large arrow indicates stocking check. Transverse section of left otolith (B) (62x, thickness 290 um). Viewed in transmitted light. Arrow indicates opaque nodule on the lateral surface.

Figure 10. Total length - anterior scale radius for juvenile lake trout from the four lakes used in the comparison. Probability levels--** = $P<0.01$ and ns = non-significant.

Figure 11. Midsummer vertical distribution of lake trout in small inland lakes (100-200 ha) in the Haliburton region of Ontario. Each data point indicates the size and depth of capture for an individual lake trout. Average temperatures at each 10-meter depth interval are also indicated. One large cannibalistic trout (C) was caught in deep water and was not used to calculate the relationship between depth and size for subadult and adult lake trout.

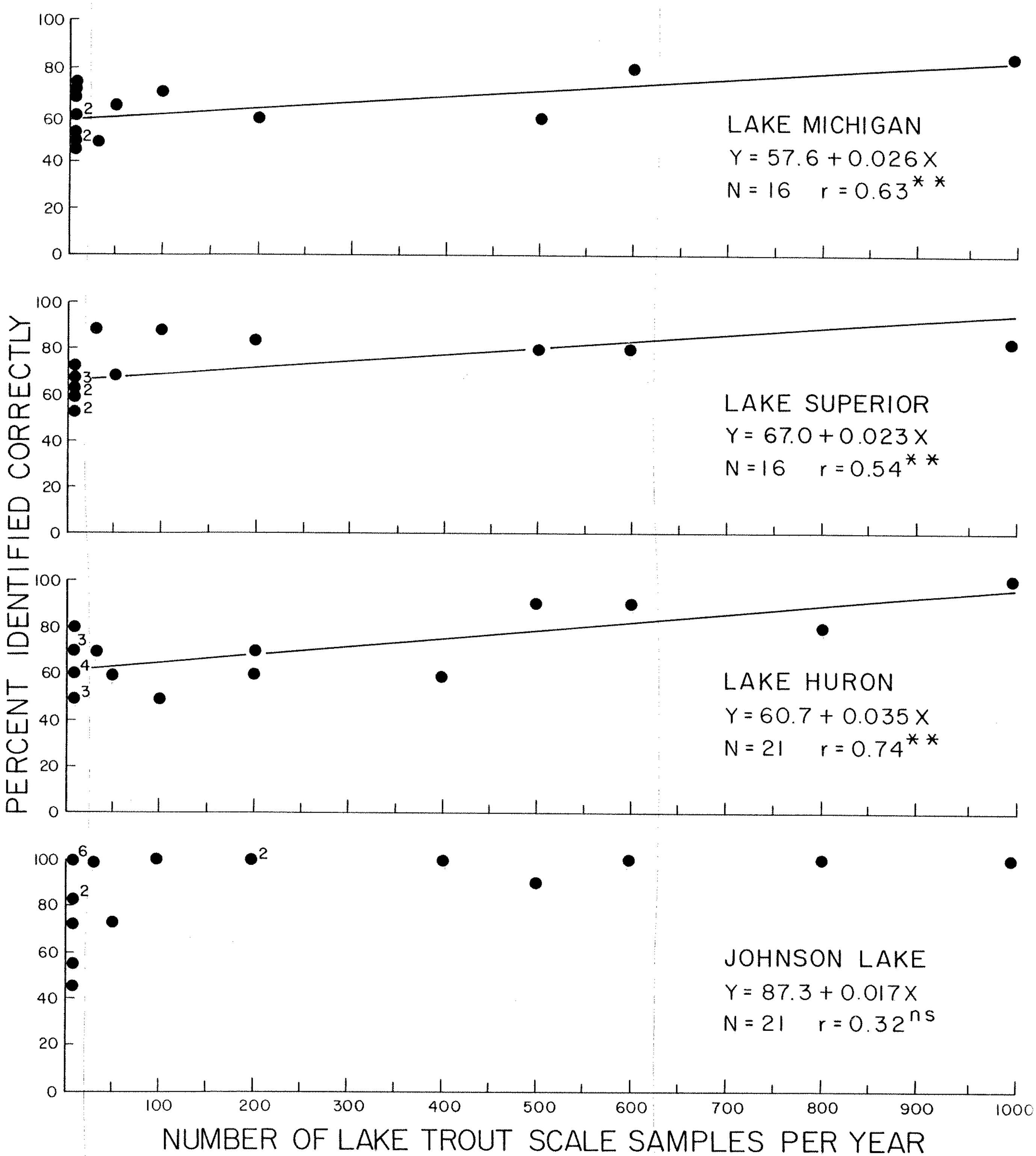
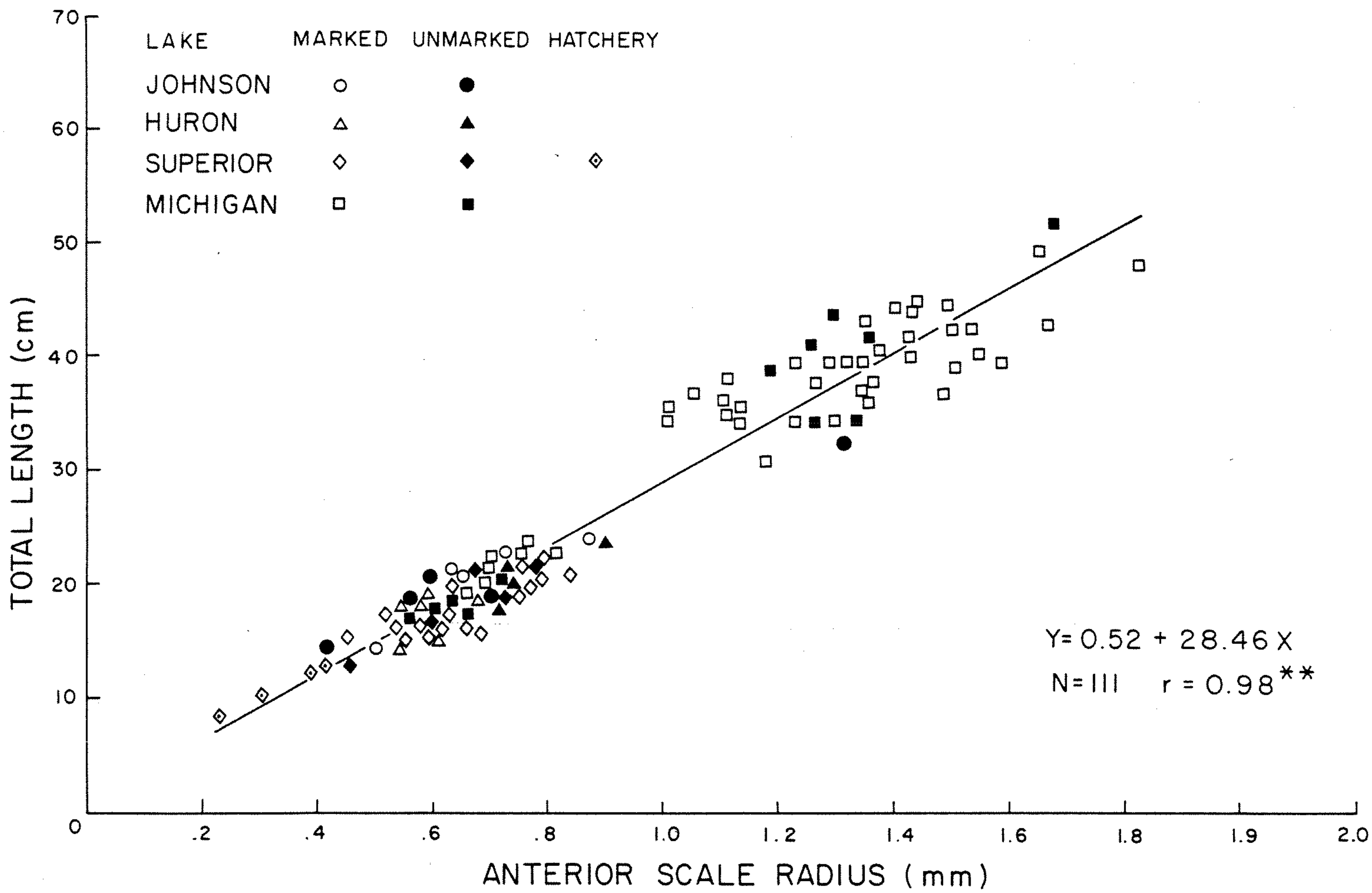
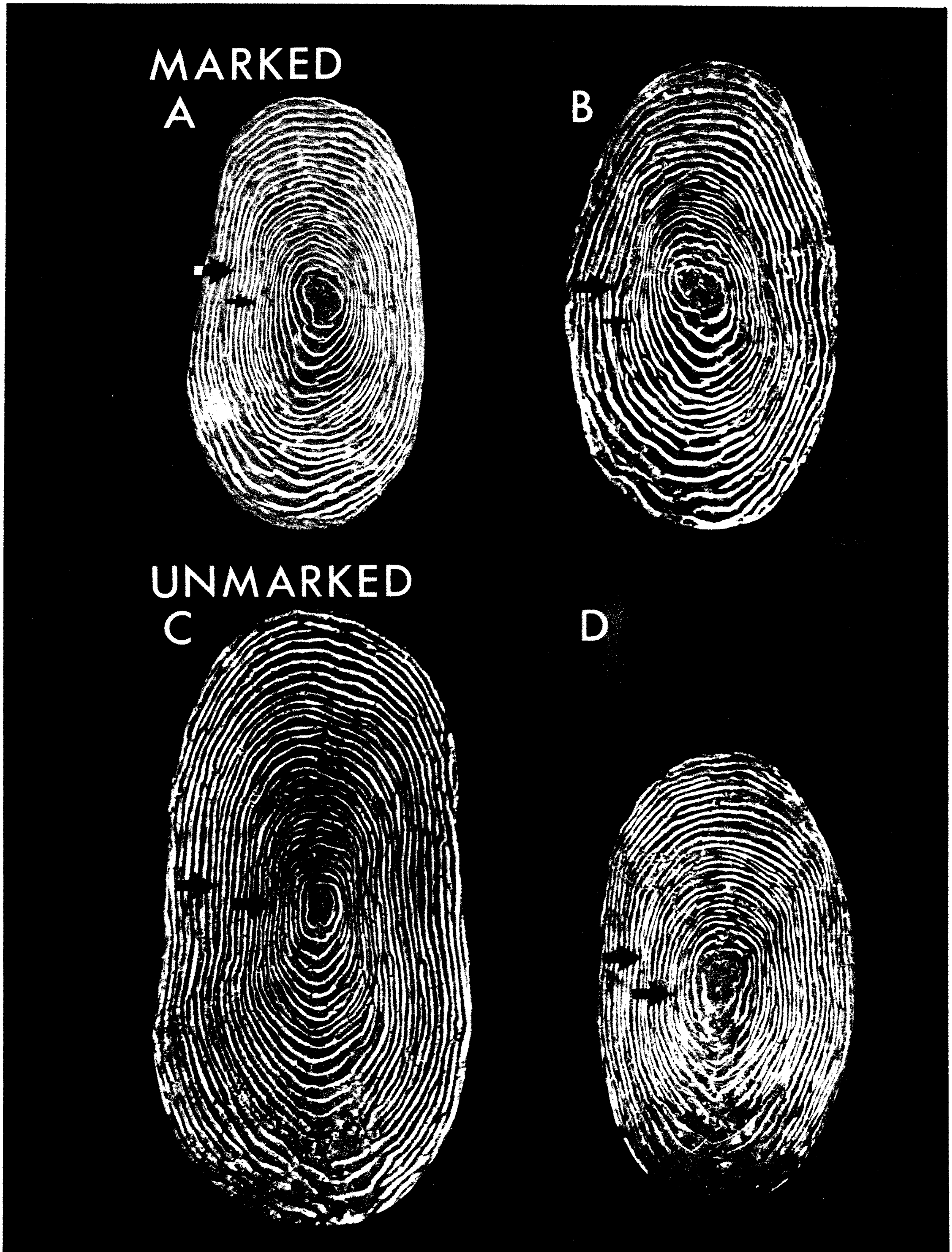

PERCENT IDENTIFIED CORRECTLY
LAKE MICHIGAN
Y = 57.6 + 0.026 X
N = 16 r = 0.63**
LAKE SUPERIOR
Y = 67.0 + 0.023 X
N = 16 r = 0.54**
LAKE HURON
Y = 60.7 + 0.035 X
N = 21 r = 0.74**
JOHNSON LAKE
Y = 87.3 + 0.017 X
N = 21 r = 0.32ns
NUMBER OF LAKE TROUT SCALE SAMPLES PER YEAR

FIG. 2



LAKE
MARKED
UNMARKED
HATCHERY
JOHNSON
HURON
SUPERIOR
MICHIGAN
Y= 0.52 + 28.46 X
N= 111 r = 0.98**
TOTAL LENGTH (cm)
ANTERIOR SCALE RADIUS (mm)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A
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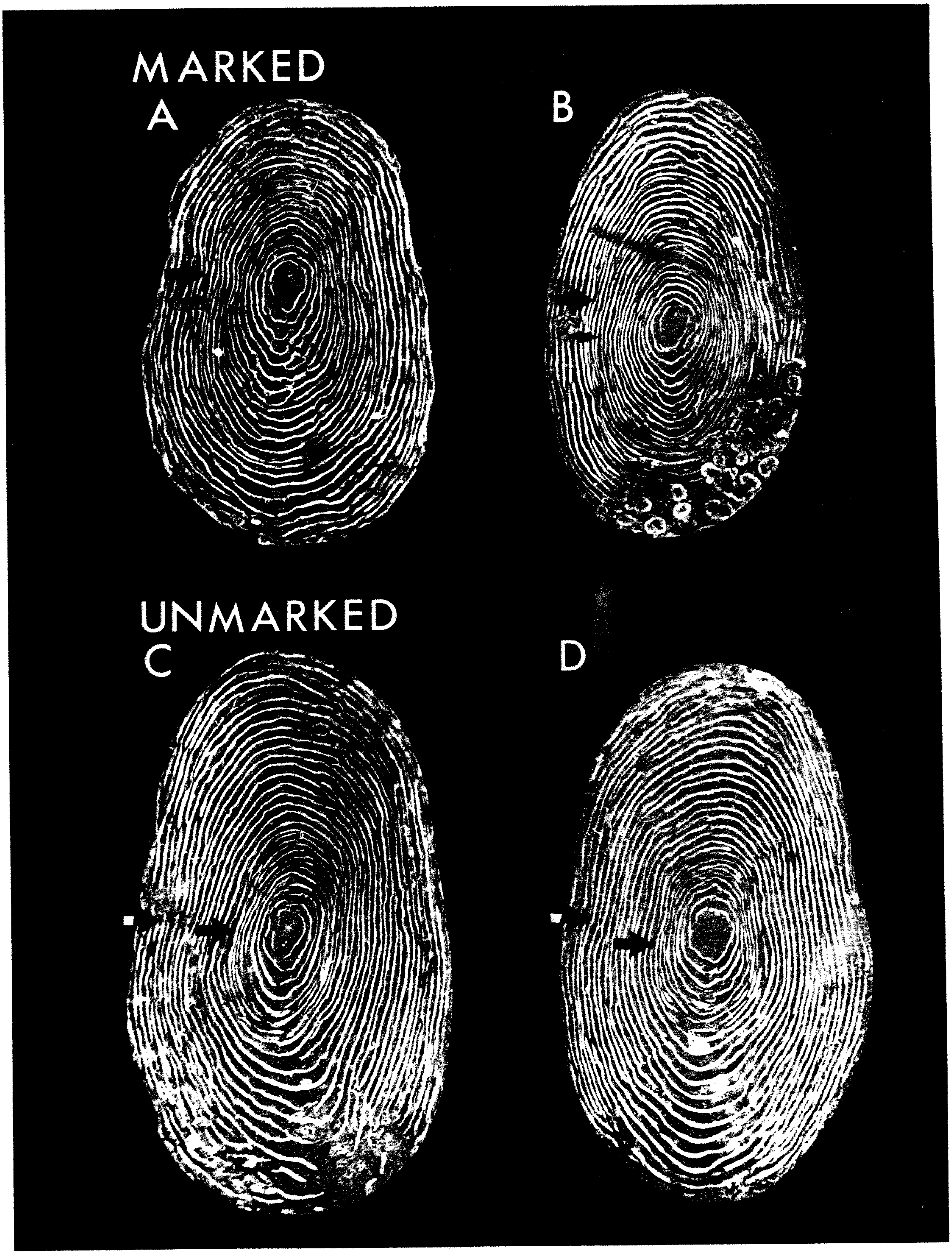
C
D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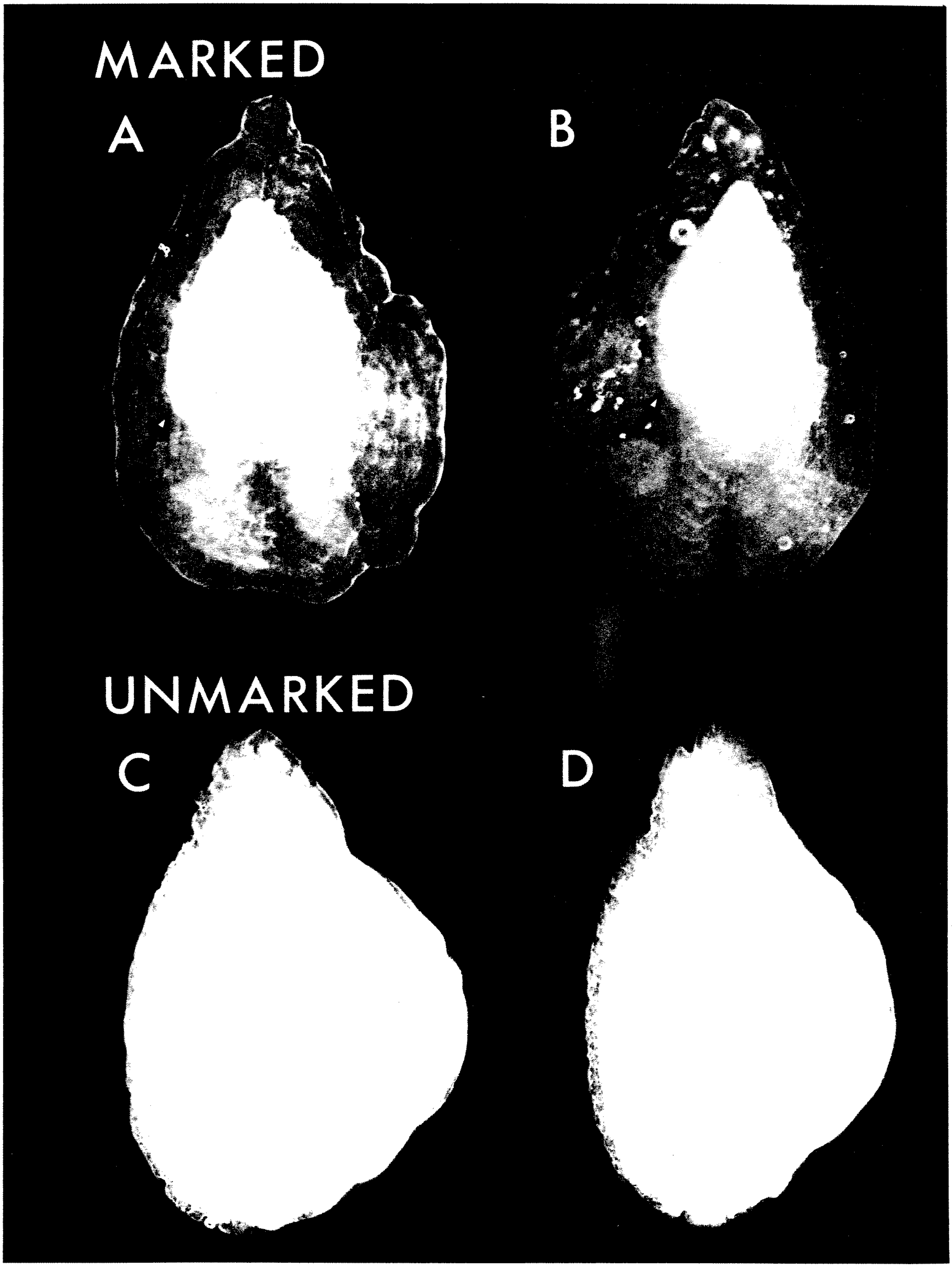
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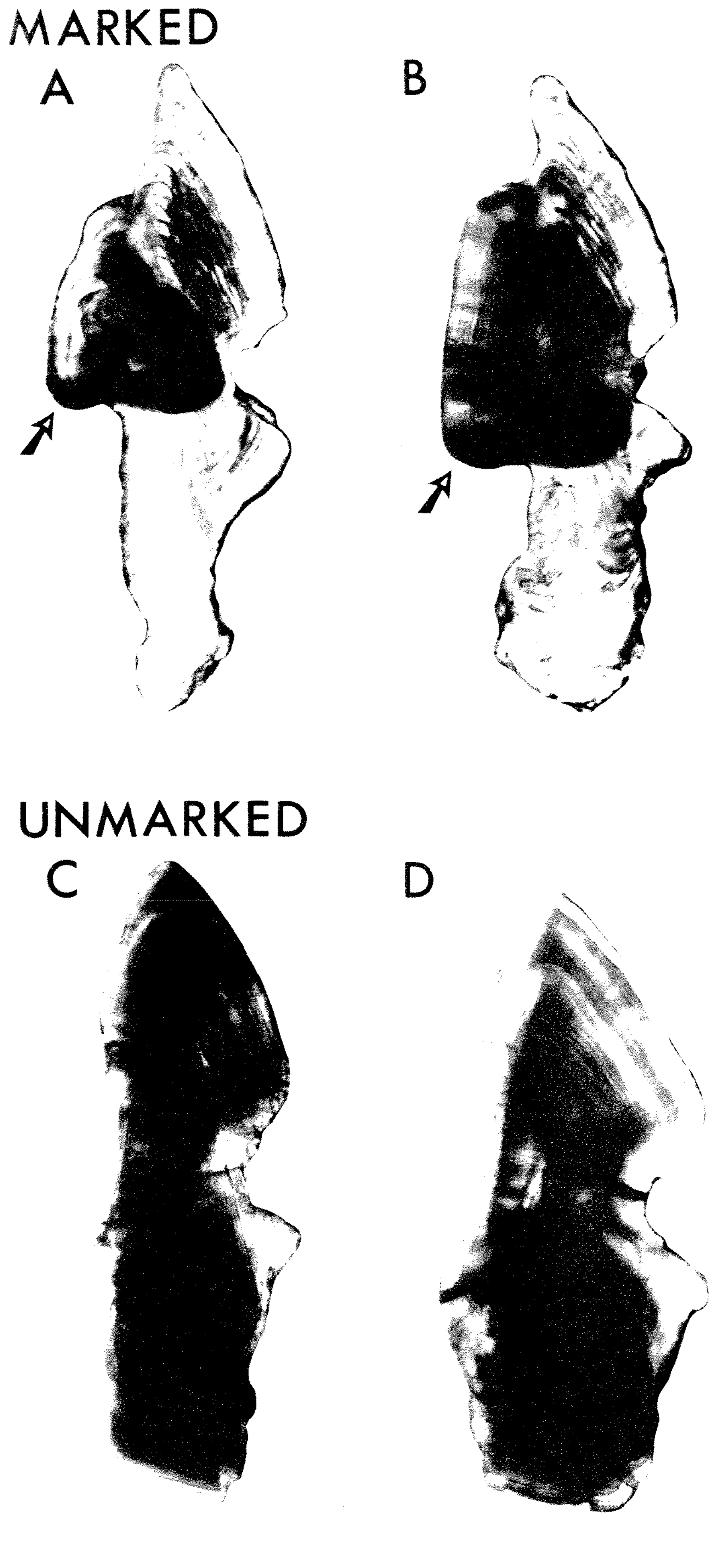
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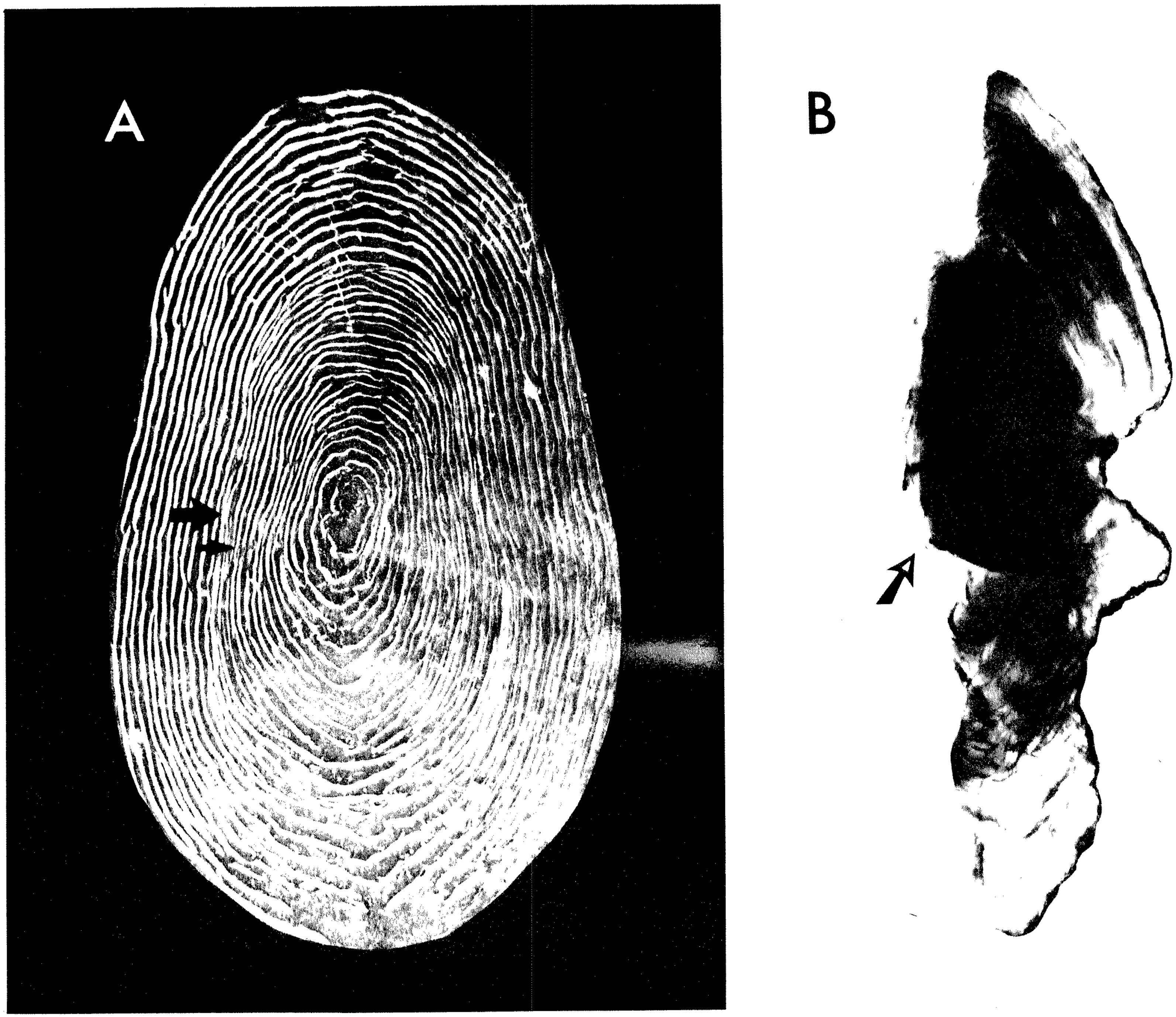
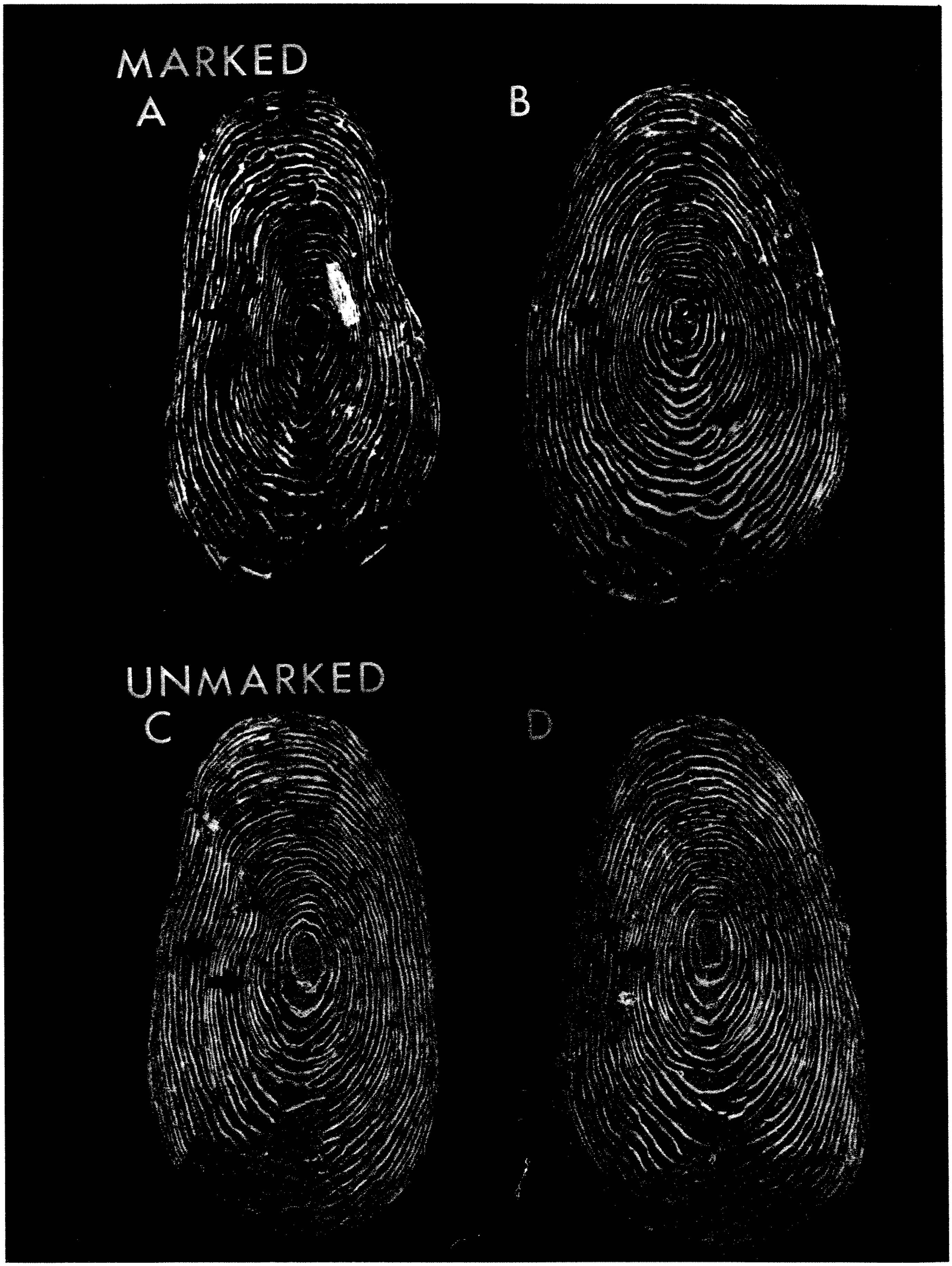

A
B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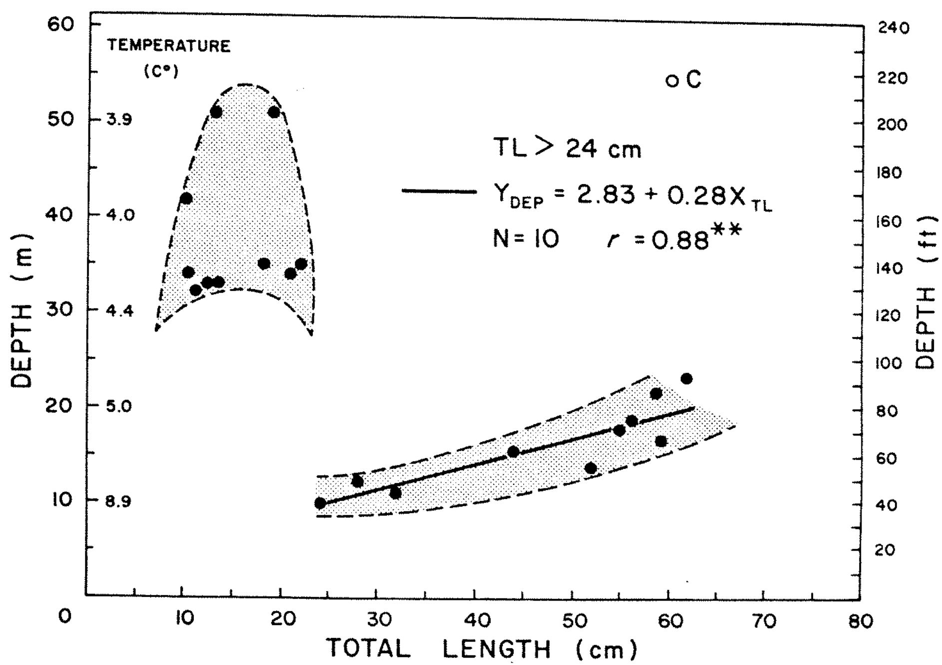

TEMPERATURE (C°)
o C
TL > 24 cm
Y DEP = 2.83 + 0.28X TL
N= 10 r =0.88**
DEPTH (m)
DEPTH (ft)
TOTAL LENGTH (cm)

FIG. 11