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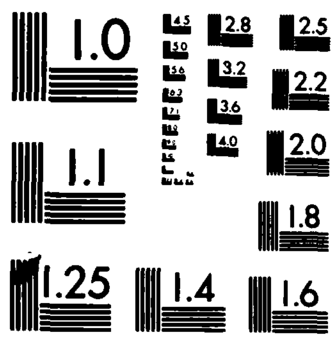

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Great Lakes Fishery Laboratory

U.S. Fish and Wildlife Service
Ann Arbor, Michigan

ADMINISTRATIVE REPORT No. 80-6

USFWS-GLFL/AR-80-6

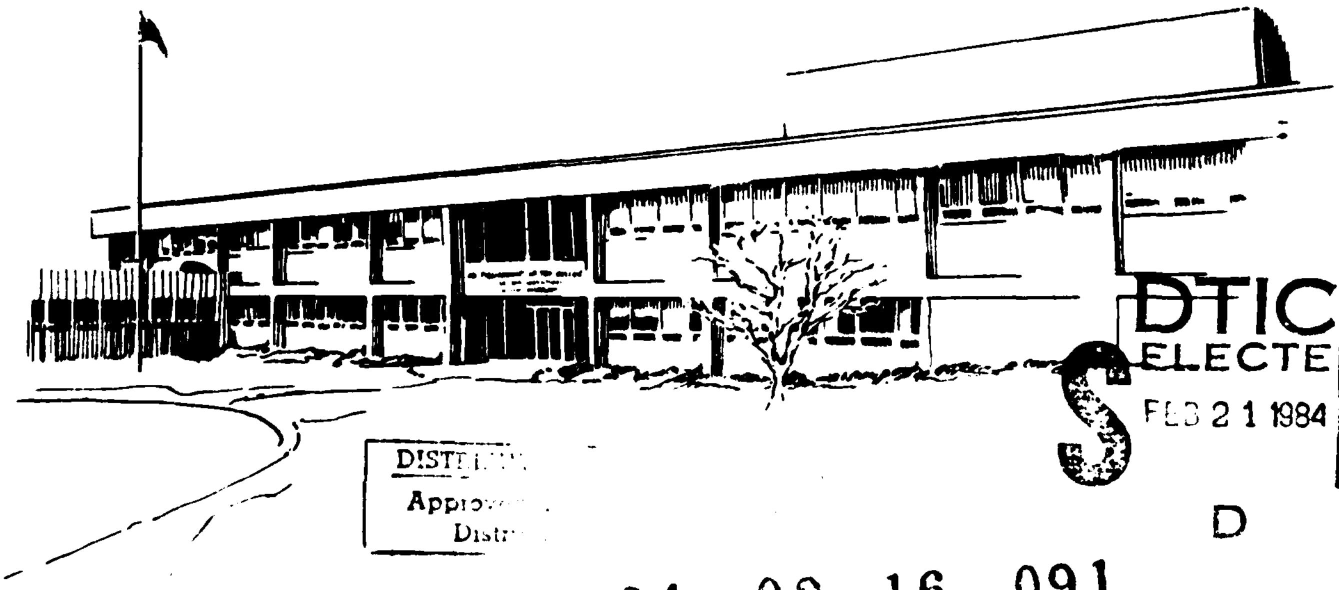
EFFECTS OF SHIP-INDUCED WAVES IN AN ICE ENVIRONMENT ON THE ST. MARYS RIVER ECOSYSTEM

Thomas P. Poe

Thomas A. Edsall

Jarl K. Hiltunen

January 1980



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The Great Lakes Fishery Laboratory agreed to provide a base of information for evaluating the effects on fish, fish-food organisms, and fish habitat at those sites of ship-induced, under-ice surge waves, created by vessel passage in the adjacent ice-covered navigation channel.

Macroinvertebrates of 56 taxa were identified in 75 Ponar grab samples taken during January-April at Frechette Point and Six Mile Point. Chronomidae (midge larvae), Oligochaeta (worms), and Gastropoda (snails) comprised about 67% of the total number of organisms collected. Pelecypoda (fingernail clams), Amphipoda (scuds), Polychaeta, Ephemeroptera (mayflies), and Trichoptera (caddisflies) were common in all samples and collectively made up about 22% of the total. The density of benthic macroinvertebrates (all taxa combined) for all stations and months was 14,125.8/m^2.

One-way analysis of variance tests (ANOVA) revealed no significant differences (α = 0.05) in mean density of benthic macroinvertebrates among samples collected at different locations, water depths, and months, but subsequent evaluation of the power of these tests showed they would have failed to detect a significant difference in mean macroinvertebrate densities between locations 45% of the time, between depths 60% of the time, and between months 70% of the time. An unequivocal demonstration of effect (or no effect) would have required analysis of additional samples to improve the power of the ANOVAs, and probably also the collection of additional unaffected baseline data during a winter or series of winters when there was no vessel traffic in the study area.

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ADMINISTRATIVE REPORT No. 80-6

January 1980

This study was conducted as part of project Number 5100 of the Great Lakes Basin Commission for the Environmental Evaluation Work Group of the Winter Navigation Board. Funding was provided by the U.S. Army Corps of Engineers--Detroit District through the Great Lakes Basin Commission.

Great Lakes Fishery Laboratory
U.S. Fish and Wildlife Service
1451 Green Road
Ann Arbor, Michigan 48105

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EXECUTIVE SUMMARY

1. On January 25, 1978 representatives of the U.S. Fish and Wildlife Service's Division of Ecological Service (FWS-ES), the Michigan Department of Natural Resources, the Detroit District, U.S. Army Corps of Engineers (COE), and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), witnessed the ramparting of ice blocks at the shoreline and the hydraulic transport of sediments and aquatic biota onto shore ice, during the passage of an ore carrier off Frechette Point in the St. Marys River; this event generated interest in an investigation of the effects of vessel-induced, under-ice surge and drawdown waves in Great Lakes connecting channels.

2. In response to requests received in November-December 1978 from FWS-ES and the COE, the Great Lakes Fishery Laboratory (GLFL) agreed to undertake a COE-funded study during January-April 1979 at selected sites in the St. Marys River, to provide a base of information for evaluating the effects on fish, fish-food organisms, and fish habitat at those sites of ship-induced, under-ice surge waves, created by vessel passage in the adjaoent ice-covered navigation channel.

3. Sampling was conducted at Frechette Point and Six Mile Point in the St. Marys River during January 16-20, February 13-19, and March 13-18, when there was solid ice cover, and during April 17-21, immediately after the solid ice cover had been broken up by heavy vessel traffic.

4. Macroinvertebrates of 56 taxa were identified in 75 Ponar grab samples taken during January-April at Frechette Point and Six Mile Point. The most abundant organisms were Chronomidae (midge larvae), Oligochaeta (worms), and Gastropoda (snails); collectively they comprised about 67% of the total number of organisms collected. Pelecypoda (fingernail clams), Amphipoda (scuds), Polychaeta, Ephemeroptera (mayflies), and Trichoptera (caddisflies) were common in all samples and collectively made up about 22% of the total. The density of benthic macroinvertebrates (all taxa combined) for all stations and months was $14,125.8/m^2$.

5. One-way analysis of variance tests (ANOVA) revealed no significant differences ($\alpha = 0.05$) in mean density of benthic macroinvertebrates among samples collected at different locations, water depths, and months, but subsequent evaluation of the power of these tests showed they would have failed to detect a significant difference in mean macroinvertebrate densities between locations 45% of the time, between depths 60% of the time, and between months 70% of the time. An unequivocal demonstration of effect (or no effect) would have required analysis of additional samples to improve the power of the ANOVAs, and probably also the collection of additional unaffected baseline data during a winter or series of winters when there was no vessel traffic in the study area.

6. Drift nets fished 98 times at Frechette Point and Six Mile Point during February 15-April 21, 1979, captured macroinvetebrates representing 24 taxa, aquatic macrophytes (Elodea), detritus, planktonic microcrustacea, and fish, but no fish eggs. Examination of the drift net fishing records and the records of vessel passages through the study area revealed a large increase in the amount of drift occurred as a result of vessel passage during the period of solid ice cover. Comparison of drift net catches in March when there was solid ice cover and moderate vessel traffic with catches in April when there was heavy floe ice and very heavy vessel traffic suggests the effect of vessel passage on drift was greater when solid ice cover was present.

7. The significance of the observed vessel-induced drift cannot be demonstrated with the available data. However, the biota and detritus represented in the drift net catches may constitute an energy resource that is important to production in the portion of the St. Marys River covered by the study. The accelerated transport of this material through the system in winter, when production approaches the annual minimum may result in a considerable energy loss to the portion of the system from which the drift material was transported.

8. A total of 132 light penetration measurements made at different levels in the water column suggested that vessel passage increased turbidity; they also suggested that the disturbance of the sediments by vessel passage was less when solid ice cover was replaced with heavy floe ice cover.

9. A total of 73 fish representing seven species was caught in gillnets, fyke nets, and traps during January-April. White suckers dominated the catch (76.7%), followed by burbot and sculpin (each at 6.8%); other species taken included yellow perch, lake herring, northern pike, longnose sucker, and ninespine stickleback. Too few fish were collected to determine if vessel passage affected fish distribution or abundance in the study area; none of the fish we collected exhibited any anatomical anomalies that we could attribute to the effects of vessel passage. The burbot was the only winter-spawning fish that we collected in the study area, and we have no evidence to indicate that burbot spawned in the study area.

INTRODUCTION

On January 25, 1978, during an inspection tour of the St. Marys River, representatives of the U.S. Fish and Wildlife Service's Division of Ecological Service (FWS-ES), the Michigan Department of Natural Resources, the Detroit District, U.S. Army Corps of Engineers (COE), and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), witnessed the passage of the ore carrier, P. R. Clarke, off Frechette Point. The vessel, traveling at a relatively high speed (11.4 mph), produced marked effects on the nearshore area including the ramparting of ice blocks at the shoreline and the hydraulic transport of sediments and aquatic biota onto shore ice.

In response to requests received in November-December 1978 from FWS-ES and COE, the FWS Great Lakes Fishery Laboratory (GLFL) agreed to undertake a COE-funded study during January-April 1979 at selected sites in Lake Nicolet, the St. Marys River, to provide a base of information for evaluating the effects on fish, fish-food organisms, and fish habitat at those sites, of ship-induced, under-ice surge waves, created by vessel passage in the adjacent ice-covered navigation channel. The GLFL also agreed to evaluate the information developed during the study along with other relevant materials, and render judgments, where possible, regarding the effect and impact of ship-induced, under-ice surge waves on the above-mentioned biota and their habitat.

As requested by COE, this study was performed under a Memorandum of Agreement between GLFL and the Great Lakes Basin Commission (GLBC), which acted as the Environmental Studies Coordinator for some of the winter navigation-related research funded by COE. According to the terms of the Memorandum of Agreement (GLBC-79-5110) some of the information needed by GLFL to select the study locations and sites and evaluate the impact of vessel passage on the biota of the St. Marys River was to be supplied by CRREL and by Lake Superior State College, who were also under contract to GLBC.

MATERIALS AND METHODS

The general study area selected by COE (Fig. 1) is located in the U.S. waters of the St. Marys River in a 25.7 mile stretch of the river identified by CRREL and COE as an area most likely to experience impact from winter navigation. Two locations within the general study area were identified by CRREL as being particularly susceptible to impact by ship-induced, under-ice surge waves; these locations were Frechette Point and Six Mile Point (Fig. 2). A third location, Nine Mile Point, (not shown on Figure 1), was also originally identified by CRREL for study. We conducted limited sampling (for macrozoobenthos) at Nine Mile Point at the beginning of the study, but because of its inaccessibility (in winter) were forced to exclude that location from further study.

At each of the two remaining locations we selected two sites for study. One site at a location was selected as a potentially high impact site and the other site as a potentially low impact, (reference or control) site (Fig. 2). Selection of the high and low impact sites was based primarily on the relative amount of vessel-induced disturbance of the physical environment observed at the various sites by CRREL and GLFL staff. Five sampling stations was established at each site along the 1, 2, and 3 m depth contours (Fig. 3).

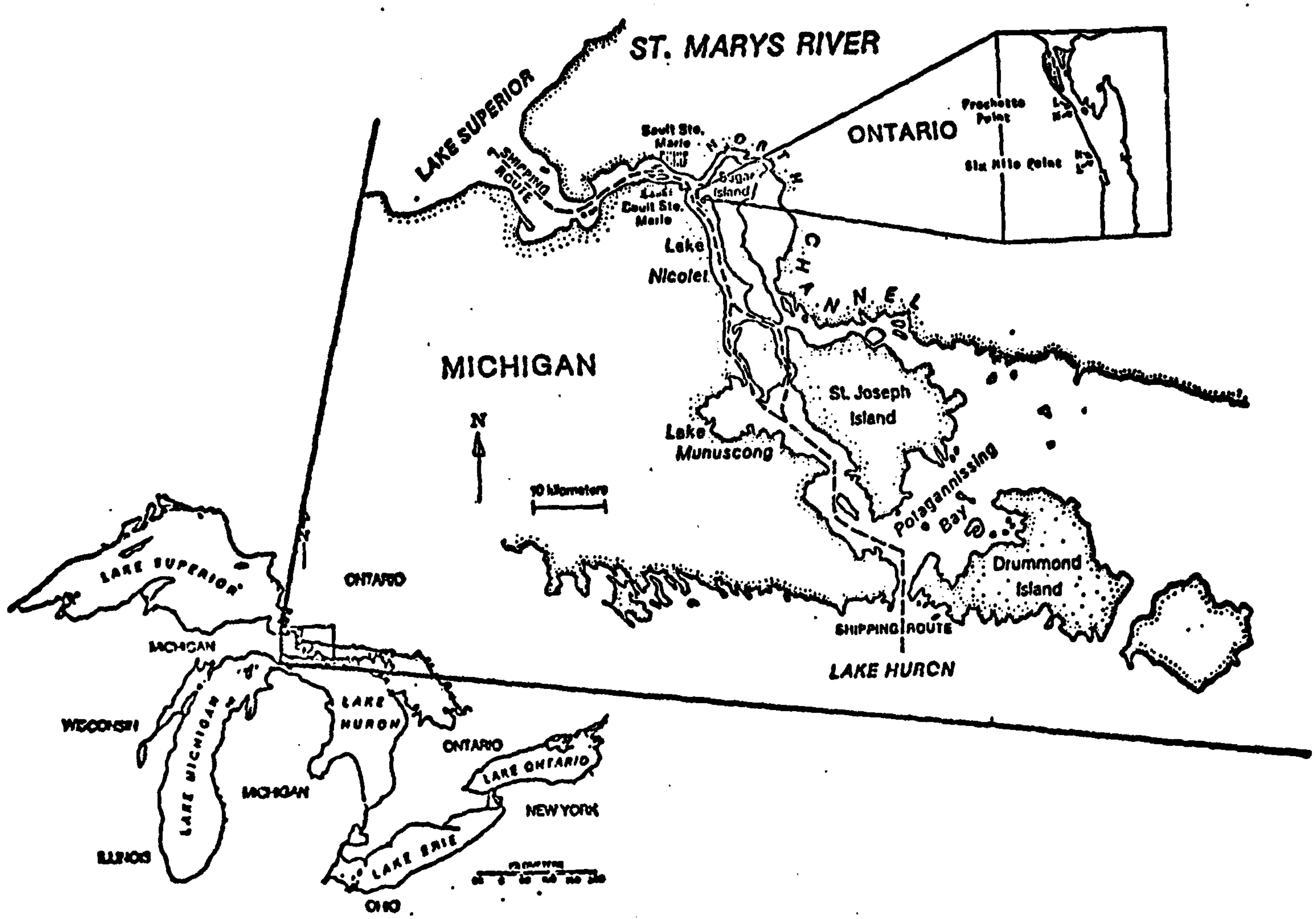
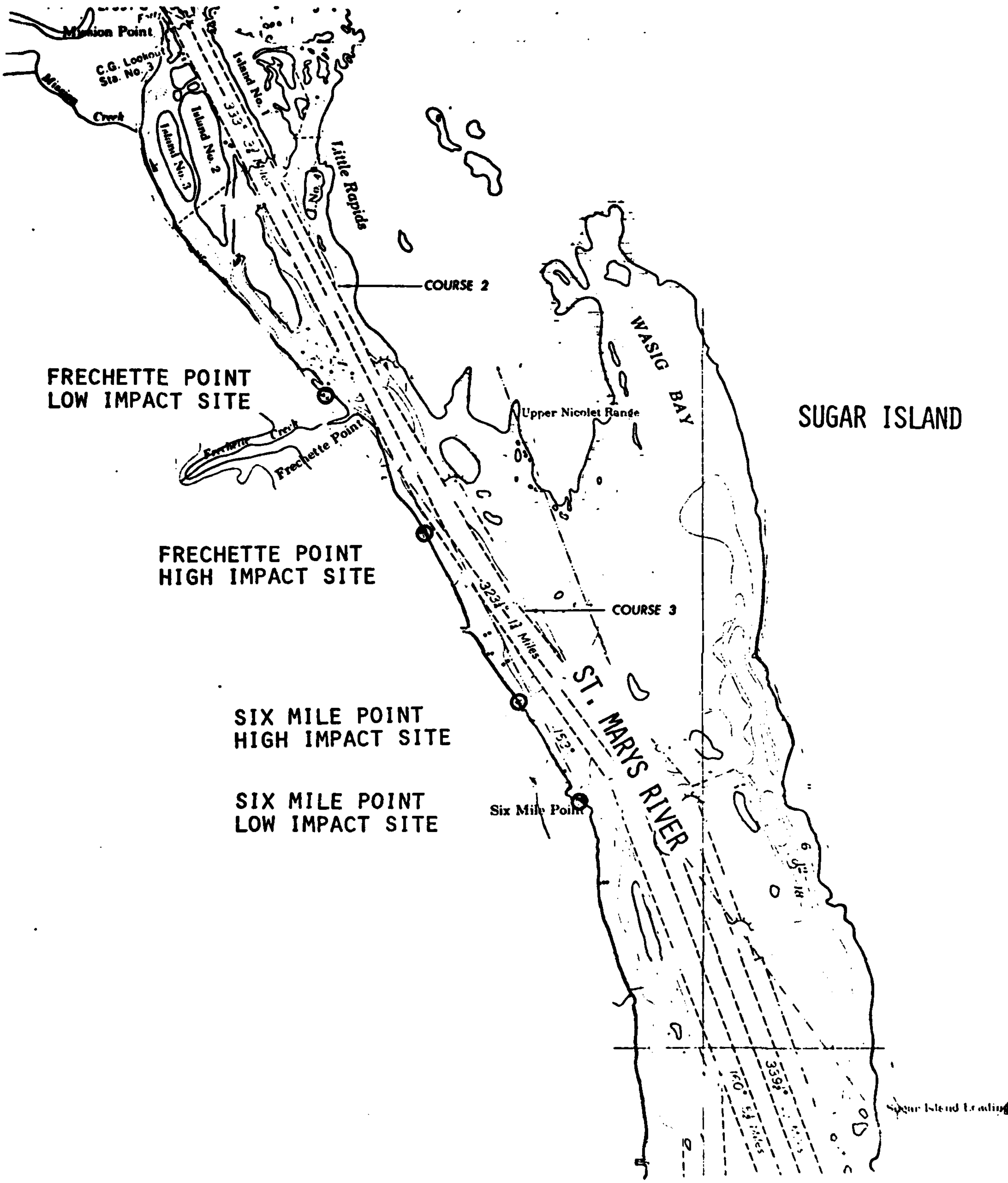


Figure 1. Location of the study area.



F gure 2. Location of the study site.

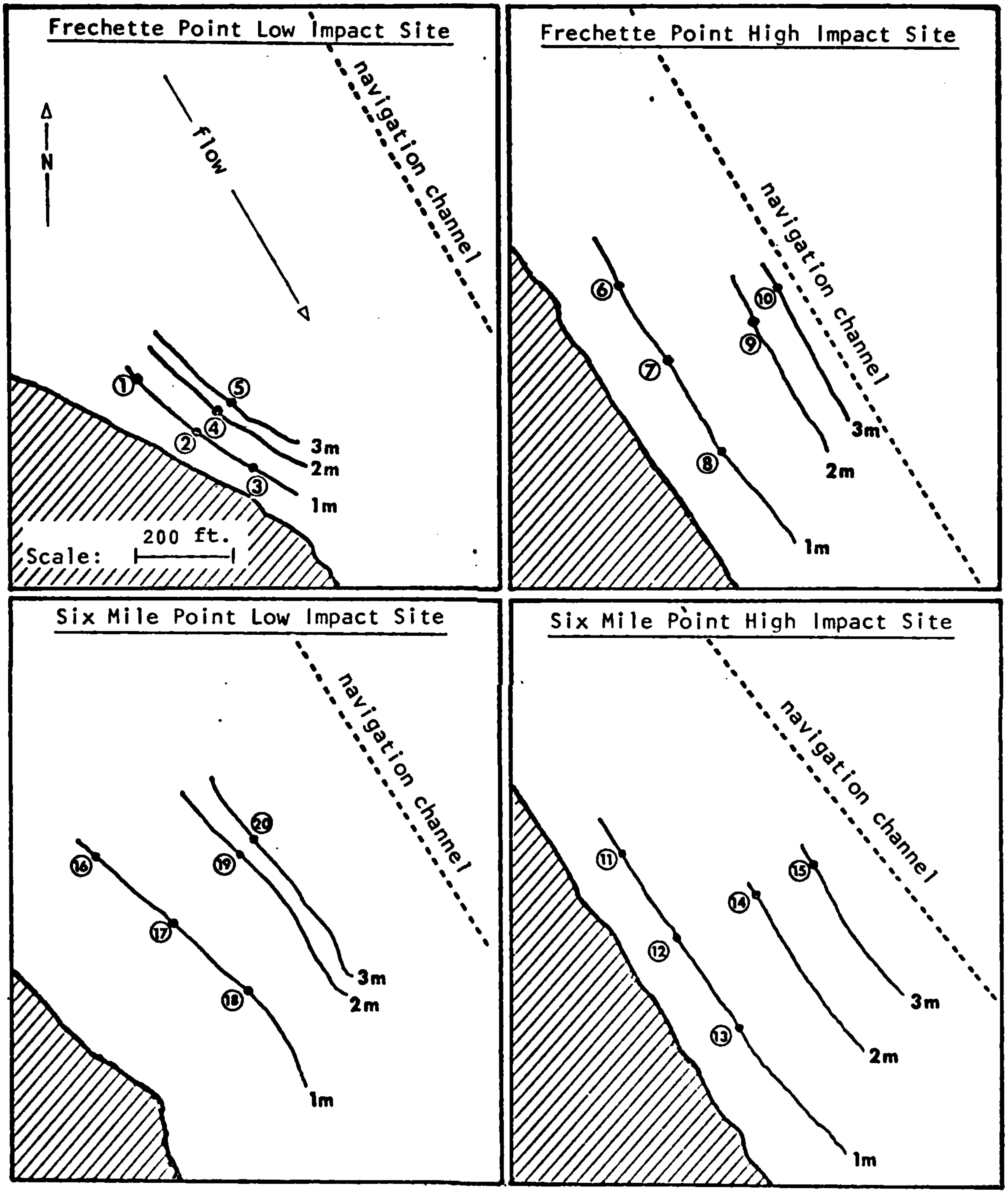


Figure 3. Station locations at Frechette Point and Six Mile Point, January-April 1979.

Benthic macroinvertebrate samples were collected with a Ponar grab at Frechette Point and Six Mile Point. At Frechette Point, three replicate grab samples were taken at each station (1, 2, 3, 4, 6, 7, 8, and 9) at the 1 and 2 m depth contours (Fig. 3). At Six Mile Point, three replicate grab samples were taken at each station (11-20) at the 1, 2, and 3 m depth contours (Fig. 3). Samples were collected once per month, January-April, at all stations listed above, except station 19, which was not sampled in February because ice cover extended to the bottom. All grab samples were washed through a U.S. standard #30 sieve and the residue was preserved in 10% formalin. Samples were taken to GLFL where the macroinvertebrates were extracted, identified, and enumerated. As set forth in the Memorandum of Agreement, only one sample from each three-replicate set was analyzed; the remaining samples were archived and are available if needed. A total of 30 samples was also taken with a Ponar grab at Nine Mile Point in January, before it was eliminated as a sampling location; all of those samples were also archived.

Drift samples were collected with standard cone-shaped plankton nets, 30 cm in diameter with 580 μm mesh. Each net was anchored in the current with a long rod; one end of the rod was driven into the river bottom and the other end extended above the ice surface. The net was fished just above the bottom and was attached to the anchor rod in a manner that allowed the net to swing freely from side to side in response to changes in direction of the current. In February, drift samples were collected at Frechette Point high impact site at four stations (7a, 7b, 7c, and 7d). These stations were located across the 1 m depth contour between stations 7 and 9; they were 57 ft apart and station 7a was 57 ft from station 7. In March and April, drift samples were taken at Frechette Point and Six Mile Point on the 1, 2, and 3 m depth contours at stations 2, 4, 5, 7, 9, 10, 12, 14, 15, 17, 19, and 20. Drift nets were fished 20, 36, and 42 times in February, March, and April respectively for a total of 808 h (average of 8.2 h per set). All material present in each drift net when it was lifted was placed in a sample jar with water and 10% formalin and taken to GLFL for processing and analysis. Each sample was processed by first extracting the macrophytes; the amount of macrophyte material was then quantified by measuring the surface area of each macrophyte fragment with a Li-cor leaf area meter LI-3000.[1/], using a method developed by GLFL (C. Brown, personal communication). Macroinvertebrates were then sorted from the samples, identified, and enumerated, using a dissecting microscope. The remaining material in the sample (detritus) was put into suspension by shaking the sample jar, and then decanted onto Whatman #1 filter paper, leaving the heavier inorganic material (such as sand) in the jar. The detritus and the filter paper were then dried 4 h at 105°C in a drying oven, and weighed to the nearest milligram on an analytical balance.

Light levels were measured in the water column with a Photomatic Model 1 submersible photometer calibrated in foot-candles. Readings were taken at the surface, middle, and bottom of the water column at stations 2, 4, 5, 7, 9, 10, 12, 14, 15, 17, 19, and 20. A total of 18 light penetration measurements was made in February, 36 in March, and 78 in April.

Sampling for fish was conducted with graded-mesh gillnets (140 ft long and 6 ft high, with 20 ft each of 1, 1-1/2, 2, 2-1/2, 3, 4, and 5 inch mesh, stretched measure), fyke nets (16 ft long x 4 ft diameter pot; 75 ft wings; 1-1/2 inch mesh netting, stretched measure), and small hardware cloth traps

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[1] Use of trade names or manufacturers' names does not imply Government endorsement of any commercial product.

(1 ft high x 2 ft wide x 3 ft long covered with 1/4 hardware cloth). Gillnets were set perpendicular to the shoreline on the 2 m depth contour at Six Mile Point (stations 14 and 19) on January 16, and left overnight; strong water currents at Frechette Point prevented us from making similar sets there, on January 16, as planned. When we lifted the gillnets at stations 14 and 19, we found them filled with macrophytes to the point that they could not have fished effectively. Because of the macrophyte clogging problem and the fact that high water velocity prevented their use at Frechette Point, we discontinued the use of gillnets and conducted all subsequent fish sampling with fyke nets and hardware cloth traps. Fyke nets were set overnight at the 2 m depth contour with the wings extending downstream; they were set at stations 9 and 14 in February and at stations 4, 9, 14, and 19 in March and April. Two fyke net sets were made in February, seven in March, and eight in April. Hardware cloth traps were set overnight at the 2 m depth contour at station 4; two traps were set in March and two were set again in April. Fish taken from the nets and traps were measured (total length in cm) and returned to the water alive.

RESULTS AND DISCUSSION

Benthic Macroinvertebrates

Macroinvertebrates of 56 taxa were identified in 75 Ponar grab samples taken during January-April at Frechette Point and Six Mile Point (Table 1; Appendix 1). The taxonomic composition was quite similar at both locations with minor exceptions; eight taxa (mostly caddisflies, Trichoptera), were collected at Frechette Point but not at Six Mile Point, and five taxa were found at Six Mile Point but not at Frechette Point. The aquatic insects (Diptera, Ephemeroptera, Coleoptera, Lepidoptera, Neuroptera, and Trichoptera) displayed the highest diversity with 29 taxa followed by mollusca (Gastropoda and Pelecypoda) with 11 taxa. The taxonomic composition of the macrobenthic fauna in the study area was very similar to that found in studies conducted on the St. Marys River in 1974-75 (Hiltunen 1978a) and in 1979 (Gleason et al. 1979) and also in the lower St. Clair River in 1977 (Hiltunen 1978b).

In the present study, the most abundant organisms were Chronomidae (midge larvae), Oligochaeta (worms), and Gastropoda (snails); collectively they made up about 67% of the total number of organisms collected (Table 2). Pelecypoda (fingernail clams), Amphipoda (scuds), Polychaeta, Ephemeroptera (mayflies), and Trichoptera (caddisflies) were common in all samples and collectively made up 22% of the total. The same major groups (Chironomidae, Oligochaeta, and Gastropoda) were also numerically dominant in other macroinvertebrate studies on the St. Marys River (Hiltunen 1978a and Gleason 1979) and on the Lower St. Clair River (Hiltunen 1978b). We found two exceptions, however--(1) gastropods (snails), which made up 45.1% of the total number of benthic macroinvertebrates taken by Gleason (1979) in the St. Marys River, but only 19.7% in the present study, and (2) oligochates (worms), which made up 49.2-62.6% of the total catch in the lower St. Clair River in Hiltunen's study (1978b), but only 22.5% in the present study.

In the present study, average densities of major groups (Table 2) ranged from 129.1/m^2 for Trichoptera (caddisfly larvae) to 3,517.7/m^2 for Chironomidae (midge larvae). These densities were quite similar to densities reported for the same groups for the St. Marys River and the St. Clair River by Hiltunen (1978a, 1978b). The only major exception was that the average density of

Table 1. Benthic macroinvertebrates collected by Ponar grab from the St. Marys River at Frechette Point and Six Mile Point, January-April 1979. [F = found only at Frechette Point; S = found only at Six Mile Point.]

Cnidaria
- *Hydra*

Tricladida

Rhabdocoela

Nematoda

Nemertinea (S)

Hirudinea

Oligochaeta

Polychaeta
- *Manayunkia speciosa*

Copepoda

Decapoda
- *Orconectes* (F)

Ostracoda

Amphipoda
- *Gammarus*
- *Hyalella azteca*

Isopoda
- *Asellus*
- *Lirceus*

Diptera
- Tipulidae (S)
- Ceratopogonidae
- Chironomidae
- Empididae
- Simulidae

Ephemeroptera
- *Ephemerella*
- *Baetisca* (F)
- *Caenis*
- *Ephemera*
- *Hexagenia*

Coleoptera
- *Haliplus* (S)
- Dytiscidae (S)

Lepidoptera

Neuroptera
- *Sialis* (F)

Trichoptera
- *Mystacides*
- *Triaenodes*
- *Cheumatopsyche*
- *Hydropsyche* (F)
- *Neureclipsis* (F)
- *Polycentropus*
- *Agrypnia*
- *Ceraclea* (F)
- *Hydroptila*
- *Setodes* (F)
- *Molanna*
- *Oecetis*
- *Phylocentropus*
- *Psycomyia* (F)

Hemiptera
- Corixidae (S)

Acarina
- *Arrenurus*

Gastropoda
- *Amnicola*
- *Campeloma*
- *Gyraulus*
- *Helisoma*
- *Lymnaea*
- *Physa*
- *Valvata sincera*
- *V. tricarinata*
- *Goniobasis livescens*

Pelecypoda
- *Pisidium*
- *Sphaerium*

Table 2. Density (average number/m^2) and relative abundance (as percent of total) of the major groups of benthic macroinvertebrates collected by Ponar grab from the St. Marys River, January-April 1979. [All stations and months combined.]

	Average number/m^2	Percent of total
Chironomidae	3,512.7	24.9
Oligochaeta	3,177.5	22.5
Gastropoda	2,786.0	19.7
Pelecypoda	1,485.5	10.5
Polychaeta	973.1	6.9
Amphipoda	478.8	3.4
Ephemeroptera	158.1	1.1
Trichoptera	129.1	0.9
All others	1,425.0	10.1
Total density for all taxa combined	14,125.8	

oligochaetes in the St. Clair River was higher than that found in the present study, probably because the samples on which the St. Clair River study was based were taken in spring and fall when oligochaete densities are normally higher than in winter.

The total density of benthic macroinvertebrates (all taxa combined) for all stations and months was $14,125.8/m^2$ in the present study (Table 2). Total density was quite variable and ranged from $1,894/m^2$ in March at Frechette Point high impact site to $25,174/m^2$ in February at Six Mile Point low impact site (Table 3). Densities were higher at the low impact sites in most instances. At the Frechette Point low impact site, densities were higher in all months except February and at the Six Mile Point low impact site they were higher in all months except March (Table 3).

Three one-way analysis of variance tests (ANOVA) were run to determine any significant differences in mean density of benthic macroinvertebrates between locations (all months, depths, and sites were pooled within each location), between the 1 and 2 m depths (all months and sites were pooled within each depth), and among months (all sites and depths pooled within months). These tests were performed on the untransformed raw count data, and, because data from benthic macroinvertebrate samples often fit a negative binomial distribution, on the count data transformed (by $\text{Log}_{10} + 1$). The results of all tests were the same: no significant differences ($\alpha = 0.05$) were found. A three-way ANOVA was not run because too few degrees of freedom were present to test the interactions between factors.

The results of the above tests suggest that vessel-related disturbance did not cause a decrease in density of benthic macroinvertebrates. The results of the ANOVAs, however, could also be interpreted to mean that control or reference sites were affected to the same degree as the high impact sites.

Because sample sizes in our study were small, we tested the power of the ANOVAs to detect significant differences that may have been present. Results of a "power of ANOVA" test (Dixon and Massey 1957) indicated that our sample sizes and sample variances would have failed to detect a significant difference (at $\alpha = 0.05$) in mean macroinvertebrate densities between locations 45% of the time, between depths 60% of the time, and between months 70% of the time. Using methods described by Kastenbaum et al. (1970) to determine sample size requirements for one-way ANOVA, we determined we would have needed 62 samples per location, over 200 samples per depth, and 40 samples per month to detect a significant difference (at $\alpha = 0.05$) in means 80% of the time, or to fail to detect a significant difference in means only 20% of the time. We have 150 archived samples collected during the study that could be processed to satisfy the sample size requirements to conclusively demonstrate whether or not significant differences exist between locations and among months; we do not have, however, a sufficient number of archived samples to permit us to conclusively demonstrate whether significant differences occur between depths.

Thus, a provisional demonstration of the effect of vessel passage on the density of benthic macroinvertebrates at the study sites will require (1) that we analyze additional samples to improve the power of the ANOVAs, and (2) that the ANOVAs show a greater decrease in density at the high impact sites. An unequivocal demonstration of effect (or no effect) would also require

Table 3. Density (average number/m^2) of benthic macroinvertebrates (all taxa combined) taken by Ponar grab from the St. Marys River, January-April 1979.

Location and site	January	February	March	April
Frechette Point				
High impact site	9,824	16,404	2,726	1,894
Low impact site	13,222	8,688	21,621	6,999
Six Mile Point				
High impact site	17,611	9,000	20,032	17,962
Low impact site	21,313	25,174	18,689	18,801

additional "unaffected baseline" data; collected during a winter or series of winters with vessel traffic through the study area.

Drift

Drift nets were fished at Frechette Point and Six Mile Point during February 15-April 21, 1979, (Appendix 2). Macroinvertebrates representing 24 taxa were identified in the drift net catches (Table 4). All but four of these taxa (Mysis, Chaoborus, Isonychia, and Paraleptophlebia) were also found in the samples taken with a Ponar grab in the study area during January 16-April 20, 1979. The presence of these four taxa in the drift net catches, but not in the Ponar grab samples is not surprising. Mysis and Chaoborus are epibenthic forms often found in the water column; and, in the nymphal form, Isonychia and Paraleptophlebia are free-ranging (nonburrowing, nonclinging) macroinvertebrates of flowing waters that are also frequently found in the water column. The macrophyte catch in drift nets consisted entirely of green, unrooted fragments of Elodea about 0.5-15 cm long. Detritus taken in the drift nets consisted mostly of small fragments of decaying plant matter of terrestrial and aquatic origin; planktonic microcrustacea present in the catch were not identified and were included in the detritus component of catch. One small sculpin (Cottus sp.) was taken in the drift nets; no fish eggs or other fish were present in the drift net catches.

Examination of the drift net fishing records and the records of vessel passages through the study area during February-April (Appendices 2 and 3) revealed that only in February could an unequivocal demonstration be made of the effects of vessel passage on drift net catch. At all other times, vessel traffic in the study area was too frequent to permit the collection of drift net samples that could serve as an unaffected baseline against which the samples reflecting the effect of vessel passage could be compared.

Drift net fishing effort and catch in February at the Frechette Point high impact site summarized in Table 5 reveals a total of 102 net hours of fishing effort expended from 0900-1700 h on February 15 to 1030 h on February 16 yielded catches of macroinvertebrates of 0-0.24 organisms/h, no macrophytes, and small amounts (0.02-0.04 g/h) of detritus (almost entirely microcrustaceans). Catch rose sharply during 1030-1230 h on February 16 to over 10 macroinvertebrates/h, over 7 cm^2 of macrophyte material, and to 0.24 g/h of detritus (mostly decaying plant matter). Catch rose moderately for macroinvertebrates during 1230-1430 h to 14/h, and sharply for macrophytes and detritus to over 16 cm^2/h and 5.38 g/h respectively. Catch of macroinvertebrates and detritus then declined during 1400-1600 h to about 8 cm^2/h and to 0.28 g/h respectively (about the same levels recorded during 1030-1230 h), while macrophyte catch continued to rise, to over 42 cm^2/h.

Information on vessel movement through the study area obtained from the U.S. Coast Guard (Appendix 3), Alger (1979), Gleason et al. (1979), and on-site observations by GLFL staff collectively revealed the following: no vessels passed the study site on February 13-15; the U.S. Coast Guard cutter, Mackinaw, passed the Frechette Point high impact site on February 16, downbound at 1015 h, and passed again, upbound at about 1030 h, followed by the P.R. Clarke at 1250 h, the C.J. Callaway at 1304 h, and the J.C. Munson at 1328 h. Apparently the low catches in drift nets lifted at 1700 h on February 15 and at

Table 4. Macroinvertebrates collected in drift nets fished at Frechette Point and Six Mile Point in the St. Marys River, February 15-April 21, 1979. [a=Not found in Ponar grab sample.]

Cnidaria	Ephemeroptera
Hydra	*Ephemera*
	Hexagenia
Hirudinea	*Isonychia*[a]
	Baetisca
Oligochaeta	*Caenis*
	Paraleptophlebia[a]
Amphipoda	
Gammarus	Trichoptera
	Mystacides
Isopoda	*Agrypnia*
Lirceus	
	Hemiptera
Mysidacea	Corixidae
Mysis relicta[a]	
	Acarina
Diptera	Gastropoda
Chaoborus[a]	*Amnicola*
Chrionomidae	*Campeloma*
Simulidae	*Gyraulus*
	Physa
	Valvata sincera

Table 5. Drift net fishing effort and catch at Frechette Point high impact site (station 7), February 15-16, 1979. [Each catch is an average value representing samples collected in four nets fished simultaneously on the 1 m depth contour.]

Effort and catch	Dates and hours nets fished				
	Feb. 15	Feb. 15-16	Feb. 16		
	0900-1700	1700-1030	1030-1230	1230-1400	1400-1600
Effort (number of net-hours fished)	32	70	8	6	8
Catch (per net-hour)					
Macroinvertebrates (number)	0	0.2	10.9	14.0	8.4
Macrophytes (cm^2 plant surface area)	0	0	7.33	26.67	42.23
Detritus (g)	0.02	0.04	0.24	5.38	0.28

1030 h on February 16 can be taken as the unaffected baseline condition, because no vessels passed the site during February 13 and 14 (no earlier records of vessel passage in February were examined), or on February 15. The Mackinaw passed the site downbound at 1015 h and, although its passage could have been expected to have increased the catch in the nets lifted at 1030 h, the data of Table 5 indicate it did so only minimally, if at all.

On its return trip upbound past the study site at 1030 h, however, the Mackinaw seems to have caused a large increase in catch of all of the components of drift in samples covering the period 1130-1230 h. An entirely satisfactory explanation for this difference in catch resulting from the downbound and upbound passages cannot be made with the available data. No records of vertical ice displacement (a measurement of under-ice disturbance that could have increased drift catches) were made during the Mackinaw's downbound passage. Gleason et al. (1979) provide a record for the upbound passage of the Mackinaw at 1030 h which indicates that the maximum vertical ice displacement was small (11.2 cm) compared to those caused by the three vessels that passed upbound at 1250-1328 h (60-64 cm). The results of Alger's (1979) study reveal that a vessel moving downstream at a given speed will cause considerably less vertical ice displacement and vertical sediment suspension than the same vessel passing upstream at the same speed; however, application of this generalization is confounded by the fact that the Mackinaw was backing upstream when it passed the study site at 1030 h. Nevertheless, the large increase in catch in the drift nets during 1030-1230 h on February 16 can be attributed to the disturbance (changes in current velocity and direction and the vertical displacement of ice and bottom sediments as described by Alger 1979, and Gleason et al. 1979) caused by the Mackinaw passing the study site and also to the disturbance caused upstream from the study site by the continued upbound passage of the Mackinaw. The large catches in drift nets lifted at 1400 h can be attributed to the passage of the P.R. Clarke, the C.J. Callaway, and the J.C. Munson at 1250, 1304, and 1328 h, respectively, and to the disturbance caused upstream of the study site by the continued upbound passage of those vessels and the Mackinaw. No vessels passed the study site during 1400-1600 h on February 16 and the relatively high catches during that period reflect only the disturbances caused at the site by the earlier passage of vessels during 1030-1328 h and the continuing disturbances upstream caused by their upbound passage.

The increase in catch of macrophytes during 1400-1600 h (over that during 1230-1400 h) while catches of macroinvertebrates and detritus decreased can be explained in part on the basis of the buoyancy of these three components of the drift net catch. Our observations of the macrophyte fragments in the water-filled sample jars revealed that these fragments were relatively buoyant, suggesting that those fragments dislodged from deposits in low current areas or broken from rooted stems by vessel-caused disturbance would remain in the water column long enough to be transported considerable distances downstream by under-ice river currents. The buoyancy of the macroinvertebrates and detritus in the sample jars was low compared to that of the macrophytes suggesting that the catch of macroinvertebrates and detritus during 1400-1600 h should indeed have decreased faster than that of the macrophytes. Bottom-seeking responses of benthic macroinvertebrates would also reduce their presence in the water column and their vulnerability to capture in the drift nets more quickly than would the passive sinking of the macrophytes and perhaps even the detritus.

Thus, the high drift catches shown in Table 5 during 1030-1600 h on February 16 can clearly be attributed to physical disturbances of the benthic and epibenthic habitat caused by vessels passing the study site.

Comparison of the average catches in drift nets for Frechette Point and Six Mile Point and for the high and low impact sites during March and April (only the Frechette high impact site was sampled in February) revealed differences which are difficult to interpret unequivocally, but which suggest areas which may require additional study. Moderately large differences were evident between the catches of macroinvertebrates at Frechette Point and Six Mile Point. Unweighted average catches based on pooled values from Table 6 for high and low impact sites for March and April at each location, and calculated as follows, showed the macroinvertebrate catch at Frechette Point (0.18 organisms/h) was about twice as large as that at Six Mile Point (0.09/h):

$$\text{Frechette Point:} \quad \frac{0.04 + 0.44 + 0.01 + 0.21}{4} = 0.18$$

$$\text{Six Mile Point:} \quad \frac{0.01 + 0.09 + 0 + 0.25}{4} = 0.09$$

Similar calculations revealed the macrophyte component of catch at the Frechette Point location (1.55 cm^2/h) was about half that at Six Mile Point (3.11 cm^2/h) and that the detritus component of catch at Frechette Point (0.23 g/h) was slightly less than twice that at Six Mile Point (0.14 g/h). Catches in drift nets at high impact sites also differed markedly from those at the low impact sites. Unweighted average catches based on pooled values from Table 6 for the two locations for March and April showed the macroinvertebrate catch at the high impact sites (0.02 organisms/h) was about 1/10 that at the low impact sites (0.23 organisms/h); macrophyte catch at the high impact site (3.92 cm^2/h) was about 5 times that at the low impact site (0.74 cm^2/h); and detritus catch at the high impact site (0.25 g/h) was about twice that at the low impact site (0.13 g/h).

Because benthic macroinvertebrates transported into the water column by vessel-induced disturbance would (for the reasons mentioned earlier) tend to settle to the bottom relatively quickly where they would not be susceptible to capture in drift nets, the observed differences in catch of benthic macroinvertebrates in drift nets at the various locations and sites could be expected to be positively correlated with their densities in the bottom populations in the immediate vicinity. The higher catch of macroinvertebrates in drift nets at the low impact sites than at the high impact sites during March-April is consistent with the higher densities of macroinvertebrates in the bottom populations at the low impact sites than at the high impact sites as shown by the Ponar grab samples of Table 3 for March-April; the unweighted average densities calculated from Table 3 for March-April are 15,027/m^2 for the low impact sites and 10,653/m^2 for the high impact sites. A similar correlation was expected between drift net catch and Ponar grab samples at Frechette Point and Six Mile Point, but was not found; the densities calculated from Table 3 were 8,310/m^2 and 18,871/m^2 respectively for the two locations. The available data do not permit explanation of these inconsistent results.

Table 6. Drift net catches, March 13-April 21, 1979.

Sampling period	Location and site	Average catch per hour: Macro-invertebrates (number)	Macrophytes (cm^2)	Detritus (g)
March 13-18	Frechette Point			
	High impact	0.04	5.12	0.25
	Low impact	0.44	0.58	0.06
	Six Mile Point			
	High impact	0.01	3.46	0.01
	Low impact	0.09	1.14	0.05
April 20-21	Frechette Point			
	High impact	0.01	0.13	0.26
	Low impact	0.21	0.36	0.36
	Six Mile Point			
	High impact	0	6.97	0.47
	Low impact	0.25	0.88	0.04

The almost complete absence of information on the source populations of the two other major components of catch in the drift nets prevents interpretation beyond that given above for the February 15-16 catches. The locations of stands of macrophytes and deposits of detritus in and upstream of the study area are not known and could not be readily determined during the period of ice cover when this study was conducted.

Comparison of the drift net catches in March with those in April permit an examination of the effect on drift of vessel passage during and after the period of solid ice cover. Catches in drift nets in March differed little from those in April. The unweighted average catches of macroinvertebrates in March and April, based on pooled values from Table 6 for all locations and sites by month calculated as follows, were virtually identical:

$$\text{March:} \quad \frac{0.04 + 0.44 + 0.01 + 0.09}{4} = 0.15$$

$$\text{April:} \quad \frac{0.01 + 0.21 + 0 + 0.25}{4} = 0.12$$

Unweighted average catches of macrophytes in March and April were also similar (2.57 and 2.08 cm^2/h, respectively), and the detritus catch in March (0.20 g/h) was almost identical to that in April (0.18 g/h).

In one respect, the lack of an apparent difference between drift catches in March and April (Table 6) is not surprising. Although the solid ice cover present in March broke up (apparently in response to icebreaker activity and heavy vessel traffic, rather than ice-melt and heavy runoff) just before sampling was conducted in April, the limnological conditions that prevailed on March 13-18 and could have influenced drift catch probably differed little from those on April 20-21. Water temperature changed little during March and April, because the river had solid ice cover in March and a heavy cover of floe ice in April. River discharge (flow) was also closely similar in both months; average discharge from Lake Superior was 1903 m^3/s in March and 1893 m^3/s in April (Alger 1979). Perhaps what is surprising is that the catch in March is so similar to that in April despite the heavier vessel traffic that occurred during the April sampling period (Appendix 3). Eight vessels passed through the study area on March 11-18, four of these during March 13-14 and 17-18, while drift nets were being fished (Appendices 2 and 3). In contrast, 30 vessels passed through the study area on April 19-21; 22 of these passed on April 20-21, while drift nets were being fished.

The lack of larger catches in the drift nets in April when vessel traffic was considerably heavier suggests that the effect on drift net catch of vessel passage through the study area was greater when there was solid ice cover than when there was only floe ice cover.

The significance of the observed vessel-induced drift cannot be demonstrated with the available data. The biota and detritus represented in our drift net catches, however, may constitute an energy resource that is important to production in the part of the St. Marys River covered by our study. The accelerated transport of this material through the system in winter, when production probably reaches the annual minimum, may therefore result in a considerable net energy loss to that portion of the system from which the material is transported.

Turbidity

Light levels were measured at the surface, middle, and bottom of the water column to determine if vessel passage increased turbidity, as shown by a decrease in light penetration. Because light penetration varied unpredictably (apparently as a result of differences in ice thickness and condition), we calculated light penetration as follows, using the light measurements at the middle and bottom of the water column:

$$\frac{\text{ft-candles at bottom}}{\text{ft-candles at middle}} \times 100 = \text{\% of light reaching bottom from middle}$$

The results indicate that light penetration at stations on the 1 m depth contour was generally lower in February than in March or April (Table 7). One exception occurred in February at station 7a at 1330-1340 when 37.5% of the light that reached the middle of the water column also reached the bottom. We also observed that light penetration in March and April was greater at the low impact sites (Table 7). The same trends observed at the stations on the 1 m depth contour also occurred at the stations on the 2 and 3 m depth contours.

Vessel passage occurred either during or just prior to all light level measurements except those taken in March (Appendices 3 and 4); therefore, we used March data as the unaffected baseline from which to measure the effects of vessel passage. With the exception of one measurement at station 7a in February, light penetration was lower in February than in March (Table 7), indicating vessel passage may have caused the decrease in light penetration observed in February. Light penetration was greater in April than in March in several instances (Table 7) in spite of heavier vessel traffic in April (Appendix 3). The breakup of solid ice cover in April may have reduced the vessel-induced disturbance of bottom sediments and permitted greater light penetration despite heavier vessel traffic.

The available data suggest that vessel passage caused decreases in light penetration (an increase in turbidity) under ice cover and that the greater decreases were caused at the high impact sites. Additional unaffected baseline data are needed for a conclusive demonstration of the effects of vessel passage on light penetration under ice cover in the study area.

Fish

A total of 73 fish representing seven species was caught by all gear during February-April (Table 8; Appendix 5). White suckers dominated the catch (76.7%), followed by burbot and sculpin (each at 6.8%); other species included yellow perch, lake herring, northern pike, longnose sucker, and ninespine stickleback. Gillnets fished twice in February caught one white sucker, and hardware cloth traps fished twice in March and twice in April caught a total of five sculpins and one ninespine stickleback. Fyke nets caught 6 white suckers (average of 3 fish/net night) in February; 11 white suckers and 1 burbot (average of 1.7 fish/net night) in March; and 38 white suckers, 4 burbot, 2

Table 7. Percent light penetration from the middle to bottom depths at 1 m (depth) stations [under ice cover] in the St. Marys River, February 16-April 21, 1979.

Site	Station	Date and time of measurement						
		2/16	2/16	3/18	4/21	4/21	4/21	4/21
Frechette Point High Impact Site		1310-1320	1330-1340	1445				
	7a	15.7	37.5					
	7c	14.5	21.6					
	7d	17.5	20.2					
	7			35.3				
Frechette Point Low Impact Site				1500	1100	1300	1500	1700
	2			46.4	73.1	59.2	50.0	53.8
Six Mile Point High Impact Site				1415	1600	1800		
	12			25.6	14.7	20.5		
Six Mile Point Low Impact Site				1400	1630	1830		
	17			33.3	22.6	75.0		

Table 8. Total number and relative abundance (expressed as percent of total) of all species of fish collected by all gear at Frechette Point and Six Mile Point, January 16-April 21, 1979.

Common name	Scientific name	Number	Percent of total
White sucker	*Catostomus commersoni*	56	76.8
Burbot	*Lota lota*	5	6.8
Sculpin	*Cottus* sp.	5	6.8
Yellow perch	*Perca flavescens*	2	2.7
Lake herring	*Coregonus artedii*	2	2.7
Northern pike	*Esox lucius*	1	1.4
Longnose sucker	*Catostomus catostomus*	1	1.4
Ninespine stickleback	*Pungitius pungitius*	1	1.4
	Total catch	73	100.0

lake herring, 2 yellow perch, 1 longnose sucker, and 1 northern pike (average of 6 fish/net night) in April. The lower fish catch in February and March indicates few fish were in the study area or that the fish in the area moved little at that time. The higher catch in April may have been due to ice breakup and early spawning-related movements in the study area.

Too few fish were collected to determine if vessel passage affected fish distribution or abundance in the study area; none of the fish we collected exhibited any anatomical anomalies that we could attribute to the effects of vessel passage. The burbot was the only winter-spawning fish that we collected in the study area, and we have no evidence that they spawned in the study area; as mentioned above, no fish eggs of any kind were collected in the drift nets.

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Appendix 1. Estimates of benthic macroinvertebrate density from Ponar grab samples taken at Frechette Point and Six Mile Point in the St. Marys River, January 16-April 20, 1979. Available from the Great Lakes Fishery Laboratory upon request.

Appendix 2. Drift net catches at Frechette Point and Six Mile Point in the St. Marys River, February 15 - April 21, 1979. Available from the Great Lakes Fishery Laboratory upon request.

Appendix 3. Record of vessel passage made through the St. Marys River for January 16-19, February 13-19, March 11-18, and April 18-21, 1979. Available from the Great Lakes Fishery Laboratory upon request.

Appendix 4. Incident light (in foot-candles) measured with a submarine photometer at the surface, middle, and bottom at Frechette Point and Six Mile Point, February-April 1979. Available from the Great Lakes Fishery Laboratory upon request.

Appendix 5. Fishing effort and catch at the Frechette Point and Six Mile Point in the St. Marys River, January 16 - April 21, 1979. [Each lift at a station represents one piece of gear fished overnight for one night.] Available from the Great Lakes Fishery Laboratory upon request.

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