DETERMINATION OF FISH COMMUNITY COMPOSITION IN THE UNTEMPERED REGIONS OF A THERMAL EFFLUENT CANAL – THE EFFICACY OF A FIXED UNDERWATER VIDEOGRAPHY SYSTEM

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Abstract. High flows and deep waters associated with thermal discharge canals invoke safety concerns and preclude the use of conventional fish sampling methodologies. Despite these challenges, it is critical that assessments of thermal effects from power generation do not rely solely on data collected in the plume, but also focus on fish living in the canal, particularly in regions above the zone of tempering influence. We deployed a fixed underwater videography apparatus to monitor the community composition and abundance patterns of fish in the Nanticoke thermal generating discharge canal on the north shore of Lake Erie from February 1, 1999 until July 31, 1999. We also compared the number of species observed using video to angling surveys, visual observations through the air/water interface and two modified netting procedures. Our results indicate that videography permitted the detection of the most species and the highest number of individuals. Variable visibility was the largest limitation of this approach. The addition of infrared lighting for low light conditions and a series of cameras positioned at several depths would be a cost effective, safe, and efficient method of assessing community structure and behaviour of fish in thermal discharge canals.

Keywords: abundance, angling, community structure, diversity, Lake Erie, thermal effects, videography

1. Introduction

The determination of fish community structure in and around thermal discharge canals is important for the assessment of how different operational and environmental conditions influence patterns of residency (Coutant, 1970). Fisheries studies in the region of the effluent plume after the heated water has left the discharge canal can be conducted using a variety of methods. Reductions in water velocity and larger expanses, often conducive to boat use, permit the deployment of conventional sampling devices. Direct assessments using trawl, gill, and trap nets, hydroacoustic surveys, SCUBA diving transects, or electrofishing provide opportunities to quantify and describe the species composition in the plume (e.g., Benda and Proffitt, 1973; Neill and Magnuson, 1974; Minns *et al.*, 1978). Indirect assessments through angler survey methodologies including creel surveys and angler

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diary programs are also useful for augmenting direct assessment approaches (Dryer and Benson, 1957; Marcy and Galvin, 1973; Moore *et al.*, 1973).

By the time the heated water from the condensers has reached the receiving waters, substantial reductions in temperature have usually occurred. This may occur in response to air temperature, the addition of cooler water for tempering purposes, and mixing with receiving water as the water exits the canal. The prescribed limits imposed by regulators to minimize the effects of extreme water temperature fluctuations and maximum temperatures on aquatic life are usually required to be met at some position near the exit of the discharge canal, immediately prior to reaching the receiving waters (Wiancko, 1981). It therefore stands to reason that fish that may enter and reside in discharge channels are subjected to more extreme conditions than fish residing in the plume. Furthermore, in some cases, fish may freely move upstream of the tempering pumps, and experience even more extreme temperatures and fluctuations (e.g., Cooke *et al.*, 2000). Fish residing in the condenser cooling water discharge of power stations may experience thermal conditions that approach their physiological limits (Schreer, Unpublished Data). To fully assess these impacts researchers must understand the residency patterns of fish in discharge canals, particularly in the regions upstream of the tempering water mixing zone.

The literature is largely void of fisheries studies in these regions, likely due to the difficulties in sampling fish in these areas. The high and variable flow regimes associated with discharge canals often preclude the use of boats, the deployment of conventional nets, or electrofishing gear. Entrained air and high flows interfere with hydroacoustic surveys. The high flows and presence of various pumps and machinery limit the effectiveness and safety of diving surveys. Furthermore, these safety concerns, and the physical configuration of the discharge canals, often exclude recreational anglers from angling in the upper reaches of the discharge canal, and negate the use of angler survey methods. Despite these challenges, it is clear that information is required.

Recently, researchers have used telemetric devices to monitor the residency and movement of fish in thermal discharge canals. Fish can either be tracked manually with a receiver (e.g., Wrenn, 1976; MacLean *et al.*, 1982), or an array of antennas can be installed that serve as check points and continually monitor the mobility of fish in the canal (e.g., Cooke and McKinley, 1999; Cooke *et al.*, 2000). This approach is very effective for monitoring the residency patterns of individual fish. Such information is essential for understanding the duration that individual fish reside in different regions, and therefore aids in our comprehension of the adverse conditions that these fish experience or avoid. This approach however, does have its limitations. Telemetry is a costly endeavor, especially if numerous fish species reside in or frequent the canal. Furthermore, it is still necessary to capture the fish to implant or attach the transmitters, and as discussed earlier, sampling fish in the canal is difficult.

A sampling approach that is safe, cost effective, efficient and capable of accurately reflecting the patterns of residency in the upper reaches of thermal discharge canals is required. One method for collecting observations on fish that is gaining in popularity is the use of fixed videography. Videography is useful because a variety of different behavioural parameters can be extracted from the recorded images including presence/absence, tail beats, species interactions, feeding, and ventilation rates. It is also regarded as being non-invasive, particularly suited to the monitoring of species sensitive to handling (Cooke *et al*., 1998).

The purpose of this study was to investigate the efficacy of videography for monitoring the patterns of fish community structure in the upper reaches of a thermal discharge canal. Further, we were interested in comparing the species documented from videography with observations collected by experimental angling, experimental netting with modified nets, and visual observations through the air/water interface. We discuss the biases and limitations for all of these methods and describe the conditions and applications best suited for these techniques. This information will be useful for the collection of data on fish residency in areas where fish are exposed to more extreme environmental and operating conditions than in the plume itself, where regulatory limits are usually based.

2. Materials and Methods

2.1. Study site and plant operation

The Nanticoke Thermal Generating Station (NTGS), located at 42°48′N 80°04′W, is an 8-unit, 4000 MWe (500 MWe each) coal-fired station situated on the north shore of Lake Erie. The station uses a once-through condenser cooling water system, taking water from Lake Erie via two submerged intakes that extend approximately 550 m offshore. The intakes are located near the 7 m depth contour. During summer stratification, water that is drawn from the lake into the forebay (where lake temperature is recorded) for condenser cooling and tempering purposes, is of epilimnetic origin, except during infrequent weather induced seiche events when colder hypolimnetic waters are forced inshore. It is therefore important to note that the station forebay is representative of nearshore epilimnetic waters fronting the station. The maximum design cooling water flow is 154 $m^3\ s^{-1}$, of which 88 $m^3\ s^{-1}$ is for condenser cooling and 66 $m^3\ s^{-1}$ is for the tempering of heated discharge water. The station discharges the heated effluent via a canal 550 m in length, 15.25 m wide, and 9.15 m deep (Figure 1). The Nanticoke Thermal Generating Station operates as a peak load station, contributing power to the grid during periods of peak demand. This typically requires 6 to 8 unit operation during the early morning, mid-day, and late afternoon periods. This ‘two-shifting’ mode creates fluctuating effluent temperatures in the discharge.

Eight tempering pumps, located approximately 50 m downstream from the uppermost end of the canal (downstream end of the discharge tunnel) draw ambient

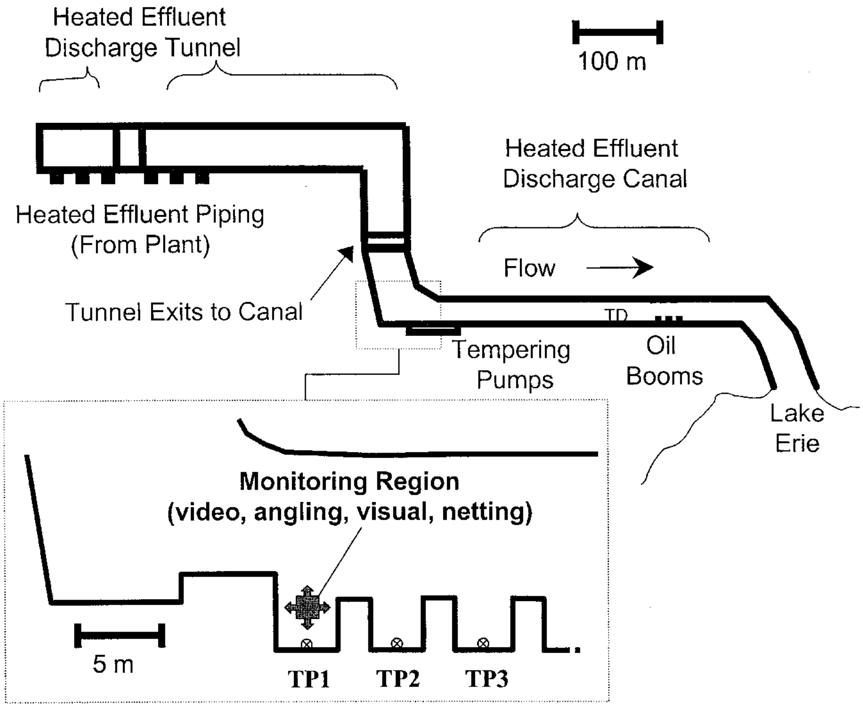

Figure 1. Map of the Nanticoke Thermal Discharge Canal on Lake Erie. The water exits the condenser tubes and runs in a large tunnel before exiting to an open channel. A series of 8 tempering pumps shunt ambient lake water from a forebay into the channel in an attempt to mitigate the effects of water temperature increases. Fish can freely swim upstream of the tempered regions where they are subjected to heightened temperatures. During the study period, tempering pumps (TP's) TP1 and TP2 were inoperational. Fish congregated in these areas because they formed velocity refuges. The only other region above the tempering pumps where fish congregated in large concentrations was in an eddy adjacent to TP1. We deployed our video apparatus, nets, angled and took visual observations at TP1. Water temperature for the lake was measured in the forebay. The location of the discharge temperature probe is labeled as 'TD'.

lake water from the forebay and mix it with the heated condenser cooling water to enable the station to meet regulatory requirements. To meet environmental objectives in place at the time of our survey ($T_{max} \leq 35$ °C, deta-T ≤ 12.5 °C) the station typically operated fewer than 4 tempering pumps. During the study TP's -1 and -2, the two most upstream pumps, were never in use and fish congregated in this area of reduced velocity. All of our observations were collected in the region upstream of the zone of tempering pump influence (Figure 1). Previous studies at the NTGS have documented that some species spend the majority of their time in the canal in untempered regions (Cooke *et al.*, 2000), leading us to chose this location for monitoring.

2.2. Water temperature monitoring

The lake temperature was measured in the station forebay, while the discharge temperature was measured by two recorders downstream from the tempering pump discharges. Discharge temperature was taken to be the average reading of two recorders; however, differences >0.1 °C were rare. Although water temperature above the zone of tempering influence was not monitored, a recent study reported that water temperatures in that region were on average 2.7 °C warmer than areas downstream (Cooke *et al.*, 2000). It must be noted that although upstream temperatures parallel temperature in the tempered zone, the difference between the two regions may not be constant due to variations in power production, condenser cooling water flow, and tempering pump operations. Both lake and discharge water temperatures were recorded hourly and summarized on a daily basis to provide a 24 hr mean, minimum and maximum. The daily thermal stability was calculated as the maximum range in discharge temperatures in a 24 hr period.

2.3. Videography

A wide-angle underwater colour camera (Deep-Sea Camera and Light Inc.) in a sealed housing (8 cm diameter, 25 cm in length) was lowered to a depth of 3 m. This depth was approximately half of the total water depth in the region where the camera was deployed. The volumetric field of view ranged from 3 to 12 m^3 based upon poor and ideal water clarities, respectively. The camera was affixed to a metal L-shaped pole to allow us to orient the camera perpendicular to the plane from which it was suspended. A sealed power and video feed cable ran from the camera to an environmental chamber located on land. A colour television, video cassette recorder, and power supply were housed in the environmental chamber. The video apparatus was operated from February 1, 1999 until July 31, 1999. Video tapes were set to begin at 9:00 and ran through to 15:00 on a given day. Such daily observations were collected at least weekly. Occasionally video was collected at other times of the day, although our viewing range was limited by low light levels. During the smallmouth bass (*Micropterus dolomieu*) reproductive period, the camera was deployed in the nesting areas of the discharge canal so limited community structure data is available for water temperatures ranging from 14 to 16.5 °C.

Post-collection data transcriptions were conducted on a Mitsubishi BV-100 video cassette machine. Playback speeds were varied between 1/5 and 1/30 of normal speeds. Where necessary, still frame advances were used. Two individuals familiar with the fish of Lake Erie conducted all transcriptions. They were able to differentiate between all species except for gizzard shad (*Dorosoma cepedianum*) and mooneye (*Hiodon tergisus*), so they were grouped. We also grouped smaller forage species including emerald shiner (*Notropis atherinoides*) and rainbow smelt (*Osmerus modax*) into 'baitfish'. On each tape, three randomly chosen 10 min observation periods were completed. Tapes were viewed at slow speed and the number of each species of fish that swam by the camera during the recording period were noted.

2.4. Angling

Numerous anglers of different ability used rod and reel angling to capture fish. A variety of artificial and live bait were used. Anglers were permitted to fish in the region surrounding tempering pump 1. Throughout the duration of the study period, anglers fished at least twice weekly. The species captured were recorded and notes on the approximate frequency of capture were also included.

2.5. Visual observations

Detailed field notes were made during each sampling trip. Visual observations were collected during equipment inspections and angling. Observations of different field assistants were discussed at the end of a sampling trip to ensure that all species observed were recorded. Only observations collected in the region of the tempering pumps were included in this analysis. Sampling was not restricted to weekdays but was limited to daylight conditions.

2.6. Netting

Two modified netting procedures were developed to use in the region of tempering pump 1. The modified gill net involved using individual 3 × 1 m panels of 5 cm mesh. Anchors and ropes were used to lower the net to the bottom in controlled fashion. The top of the net was held up by another set of ropes. Nets were fished for 2 min periods. Additional description of this technique is provided in Cooke and McKinley (1999). A modified hoop net was also used. The wings were removed and the net (1 m diameter × 3 m) was lowered to the bottom. The net was set against a cement retaining wall to lead the fish into the net. The hoop net was set for 2 to 4 hr at a time. Both of these techniques were deployed monthly throughout the study period.

2.7. Fish metrics

To examine seasonal patterns in community structure in the discharge, we calculated several metrics useful for making comparisons over time using the videography data. First, species richness (S), defined as the total number of different species present, was determined. Next, we calculated the Shannon-Wiener index of diversity (H) using the methods described by Krebs (1989):

$$H - \sum_{i=1}^{S} Pi(\ln(Pi)) \ .$$

The Shannon-Wiener index incorporates species richness and the proportion of each species (Peet, 1974). Additionally, we calculated evenness (E) using the formula:

$$E = H/\log(S) \, .$$

Evenness is a measure of how similar the abundances of different species was (Washington, 1984). We also determined the relative abundance of fish (T) that was a summation of the number of fish observed during a 10 min observation period.

2.8. Statistical analysis

Model-1 one-way ANOVA's with the Tukey multiple comparison post-hoc test were used to explore mean water temperatures on a monthly basis (six months) in both the lake and the discharge canal (Day and Quinn, 1989). Pared t-tests were used to compare the mean daily discharge temperature to mean daily lake temperature. Regression equations were generated for the four biological metrics and mean daily discharge water temperature and for the water temperature parameters (lake and discharge min, max, mean) and the day of the study. We compared the species and relative abundance (common, rare, never observed) of fish species detected over the entire study period. No statistical comparison was conducted on this data as only the videography data provided truly quantitative estimates. In all cases, data were only collected during day light conditions so we were unable to assess community structure at night. All values are presented as means ± 1 SEM. All tests were considered significant at $\alpha = 0.05$.

3. Results

3.1. Water temperatures

The Nanticoke Thermal Generating Station discharge canal was thermally altered resulting in consistently warmer conditions than in adjacent regions of Lake Erie (see description of lake temperature monitoring in Sections 2.1 and 2.2). Mean daily temperatures in the discharge canal were always higher that those of the lake ($t = 49.164$; $p = < 0.001$) and had a mean difference of 6.53 ± 0.13 °C over the monitoring period (Figure 2). Lake and discharge temperatures were fairly low and stable during February and March, and were not significantly different between months. In April, water temperatures rose sharply and continued to rise until the end of July in the lake and the discharge canal. Between April and July, monthly mean water temperatures differed significantly (Anova, $P < 0.001$) in both the lake and discharge canal.

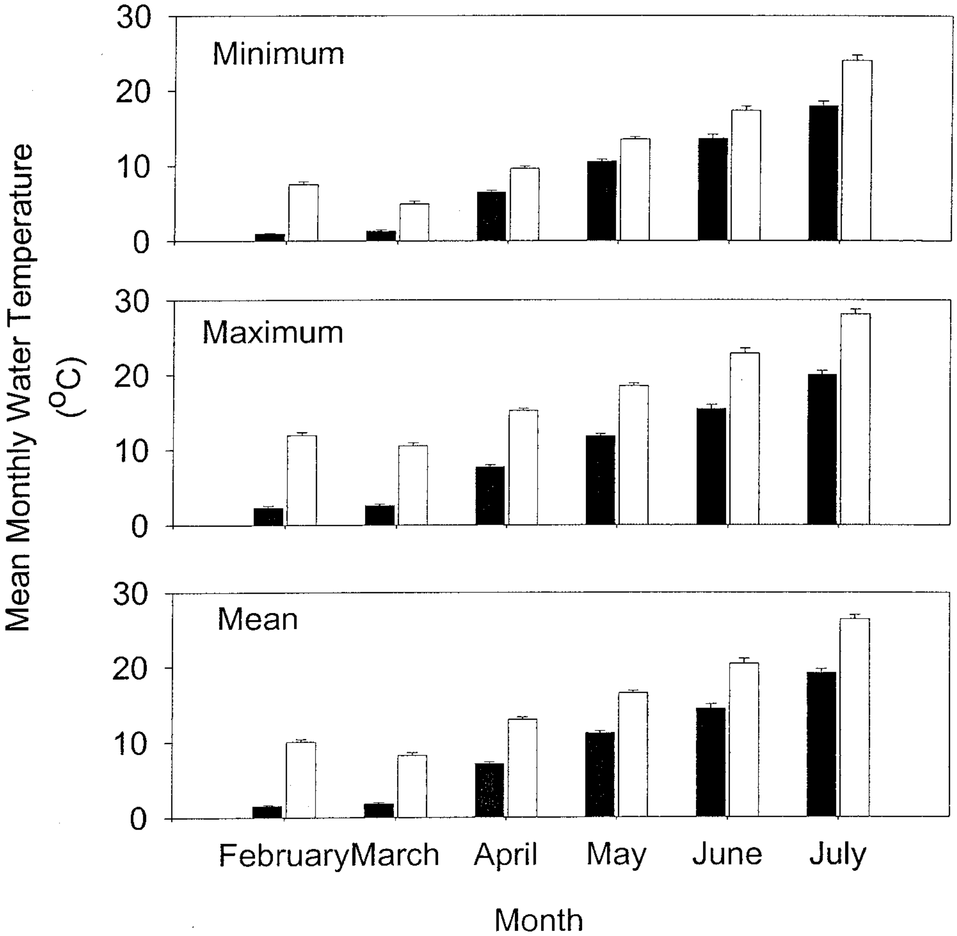

Figure 2. Mean monthly water temperatures monitored in both Lake Erie (black bars) and the Nanticoke Thermal Discharge Canal downstream of tempering pumps. Daily minimum, maximum and mean temperatures were used to determine monthly mean temperatures. For all paired monthly water temperatures, the discharge canal is significantly warmer than the lake (Paired *t*-tests, P's < 0.001). All months are different from each other except for both lake and discharge temperatures (mean, minimum and maximum) in February and March.

3.2. Techniques comparison

Videography detected the most species (14), 36% more than angling (9), and 43% more than visual observations (8) (Figure 3). The netting techniques were much less effective, capturing four species (primarily smallmouth bass) in the modified hoop nets and only one species (channel catfish (*Ictalurus punctatus*)) in the modified gill net. Three species were detected by videography that were not detected using other methods (pumpkinseed (*Lepomis gibbosus*), lake whitefish (*Coregonus clupeaformis*), walleye (*Stizostedion vitreum*)). There were two species that were

Common Name	Types of Observations					Habitat	
	Angled	Video Observations	Visual Observations	Netting (modified hoop)	Netting (modified gill)	Feeding Preference	Depth Preferred
Channel Catfish	black	black		gray	black	F,S	P,B
Chinook Salmon	gray					F	P
Common Carp	gray	gray	black			S,I	S,B
Freshwater Drum	black	black	gray			I,F	B
Gizzard Shad		black	black			I,Z	P
Lake Whitefish		gray				F,I	P
Largemouth Bass		gray	gray			F	P
Longnose Gar	gray		black	gray		F	S
Mooneye		black	black			I,Z	P
Pumpkinseed		gray				F,I	P
Rainbow Trout	gray	gray				F,Z	P
Rock Bass	black	black		black		F,I	P
Smallmouth Bass	black	black	black	black		F,I	P
Walleye		gray				F	P
White Bass	gray	gray				F	P
Baitfish (Emerald Shiner, Smelt)		gray	black			Z,I	S

Figure 3. Detection efficiency of different methodologies employed in the Nanticoke Thermal Generating Station Discharge Canal in the region of TP1. Three different tones are used to differentiate between the frequency with which fish were observed using the different techniques (black = common; gray = rare; white = never). Additionally, two habitat/life-history descriptors are included to elucidate why different monitoring approaches had different detection efficiencies. Feeding preference was classified based upon the most frequent food items consumed by adult fish in lakes (F = fishes; S = scavenge; I = invertebrates; Z = zooplankton) as determined from Scott and Crossman (1973). Depth preferred is generalized habitat type used by different species (P = pelagic; B = benthic; S = surface).

not observed by videography, but were documented by angling (Chinook salmon (*Oncorhynchus tshawytscha*)) and angling and visual observations (longnose gar (*Lepisosteus osseus*)).

3.3. Fish metrics

The abundance of fish in the discharge canal as documented by videography showed seasonal trends that are largely a result of water temperature. The abundance of fish in the discharge was similar between February and March, but peaked in April, and then declined slowly in May and June, and reached lowest levels in

TABLE I

Mean daily biological metric relationships with mean daily discharge water temperature. All relationships were significant at the $p < 0.05$ level

Metric	Polynomial model - 2nd order (quadratic)						r^2
Total abundance (T)	T = 17.72	+	26.0725	temp	–	0.11209 $temp^2$	0.47
Richness (S)	S = –0.8027	+	0.62353	temp	–	0.01896 $temp^2$	0.37
Shannon-Wiener (H)	H = 0.27337	+	0.07315	temp	–	0.00238 $temp^2$	0.17
Evenness (E)	E = 2.9183	–	0.194	temp	+	0.0059 $temp^2$	0.40

July (Figure 4A). The overall relative abundance of fish followed a parabolic trend when correlated ($P < 0.05$) to mean daily discharge water temperature (Figure 5A) (Table I). In general, abundances were highest at low to intermediate temperatures. As water temperatures approached 25 °C, relative abundance had approached near zero levels.

Seasonally, species richness had a parabolic distribution (Table I), with the highest richness values being recorded in May (Figure 4B) at intermediate water temperatures ranging from 14 to 19 °C (Figure 5B). The richness metric was significantly correlated to mean daily water temperature in the discharge canal. The richness was very reduced at water temperatures above 25 °C. Diversity followed a similar, but less distinct trend (Figure 4C, Table I), with the May value indicating heightened diversity, coinciding with about 15 °C (Figure 5C). The abundance of different species as indicated by the evenness metric, was most similar in April (Figure 4D) at water temperatures ranging from about 12 to 20 °C (Figure 5D). All of the other months had more combinations of common and rare species.

Smallmouth bass were present throughout the study period, but relative abundances differed (Figure 6A). Smallmouth bass were most abundant in May at which time they comprised about 50% of the total fish present. Smallmouth bass were least frequent in July, although they comprised the majority of those fish observed (approximately 70% of the fish). Gizzard shad and mooneye (6B) were present in intermediate densities in February and March, and comprised about 50% of the community composition. Their abundance peaked in April, although they still only comprised 50% of the fish present. In May their abundance and proportion of community composition decreased and then fell to near zero levels in June and July. Freshwater drum (*Aplodinotus grunniens*) (6C) were absent from samples until April when they comprised nearly 50% of individuals in the community. This reduced sharply by May and they were again at near zero levels for June and July. Common carp (*Cyprinus carpio*) (6D) were present in low numbers throughout the study period and were only absent during February. Channel catfish (6E) were also rare throughout the study, but were most prevalent during May.

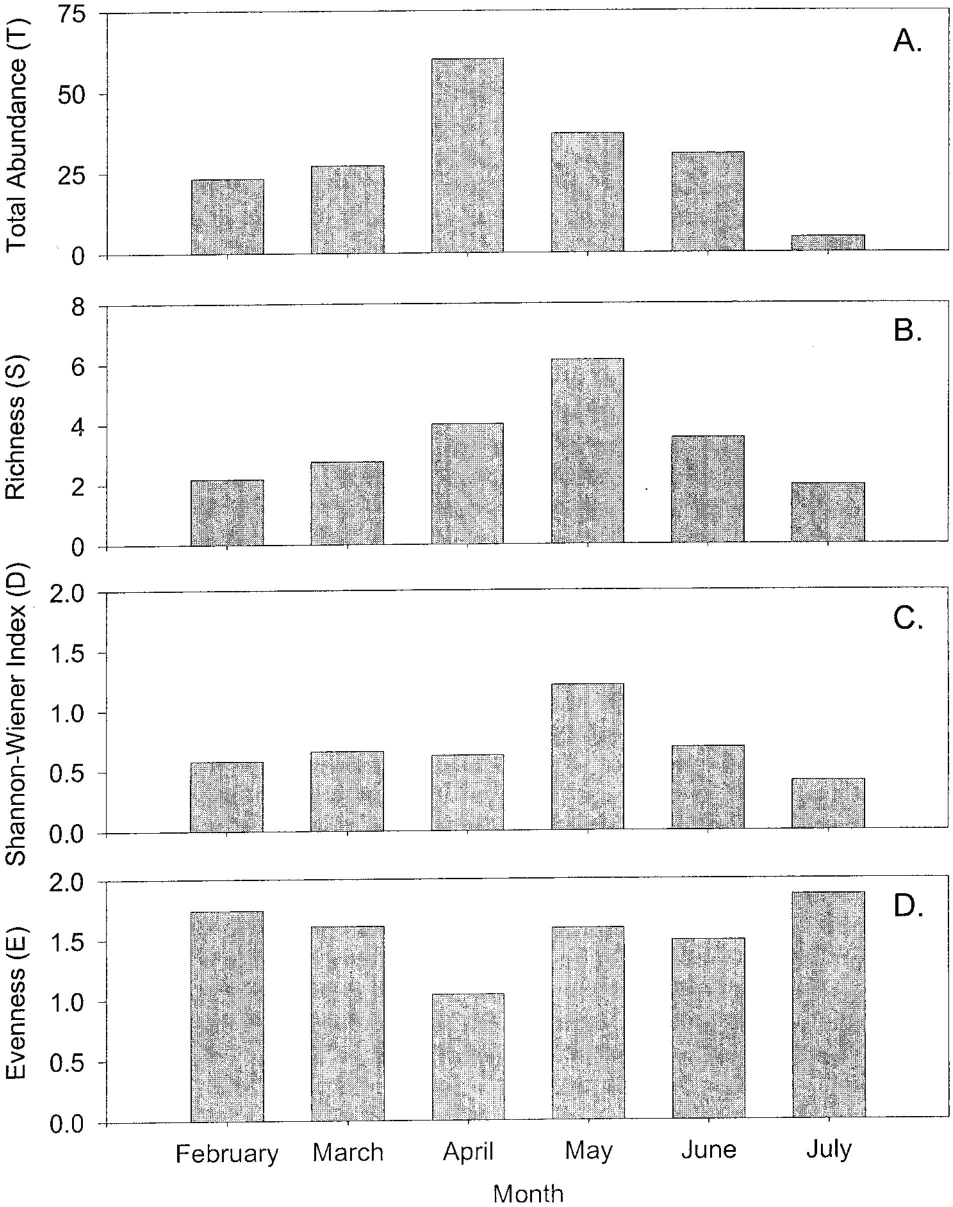

Figure 4. Monthly trends in community structure in the untempered region of the Nanticoke Thermal Generating Station Discharge Canal. Community composition was determined for three ten minute video periods per sampling day. Monthly mean values are plotted. The total number of fish (4A), species richness (4B), Shannon-Wiener Diversity Index (4C), and species evenness (4D) were calculated as described in the materials and methods section.

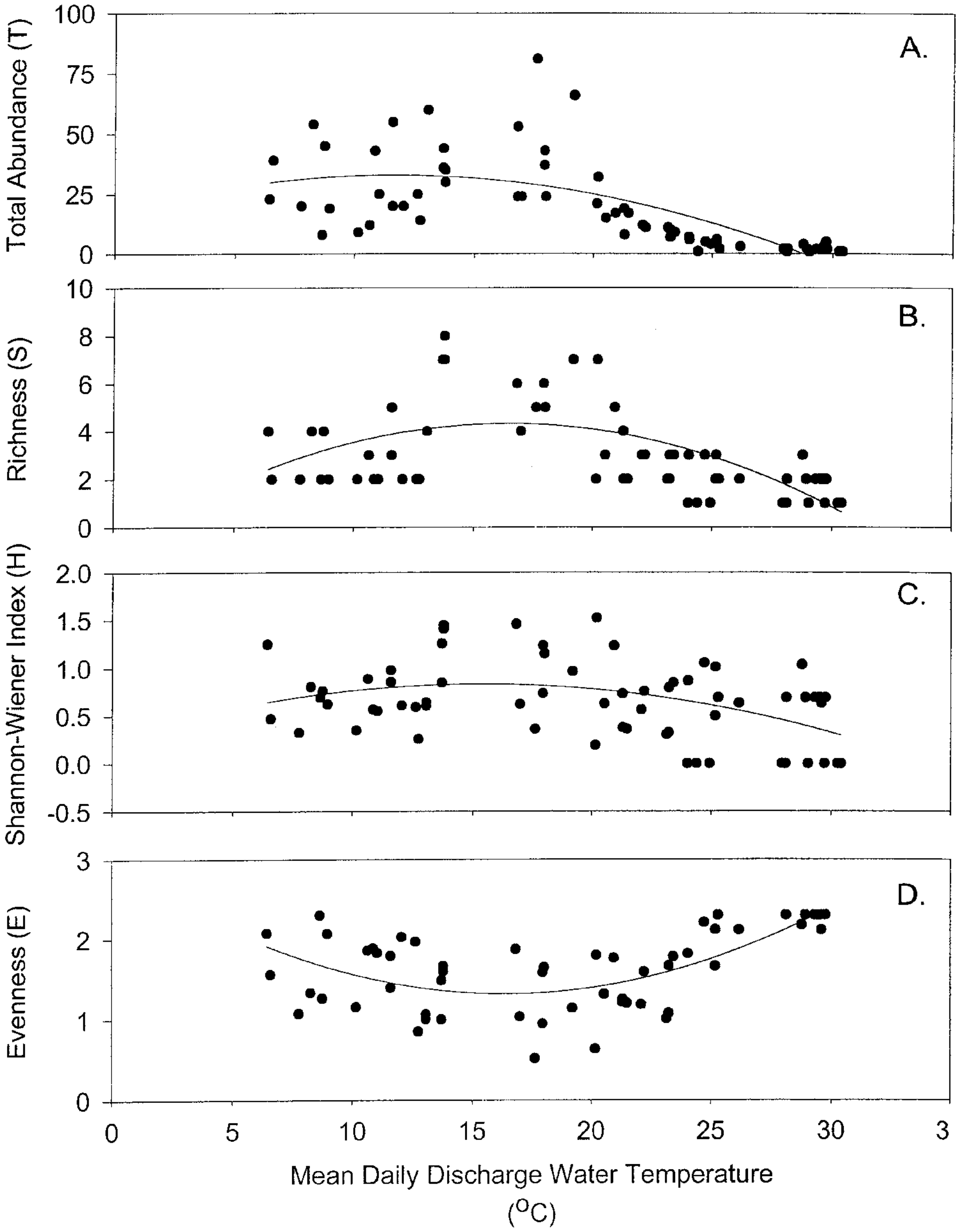

Figure 5. Daily trends in community structure in the untempered region of the Nanticoke Thermal Generating Station Discharge Canal correlated to mean daily discharge water temperature. Community composition was determined for three ten minute video periods per sampling day. Mean daily values are plotted. The total number of fish (4A), species richness (4B), Shannon-Wiener Diversity Index (4C), and species evenness (4D) were calculated as described in the materials and methods section. Quadratic equations were generated for each data set (Table I) and trend lines were plotted on the graphs.

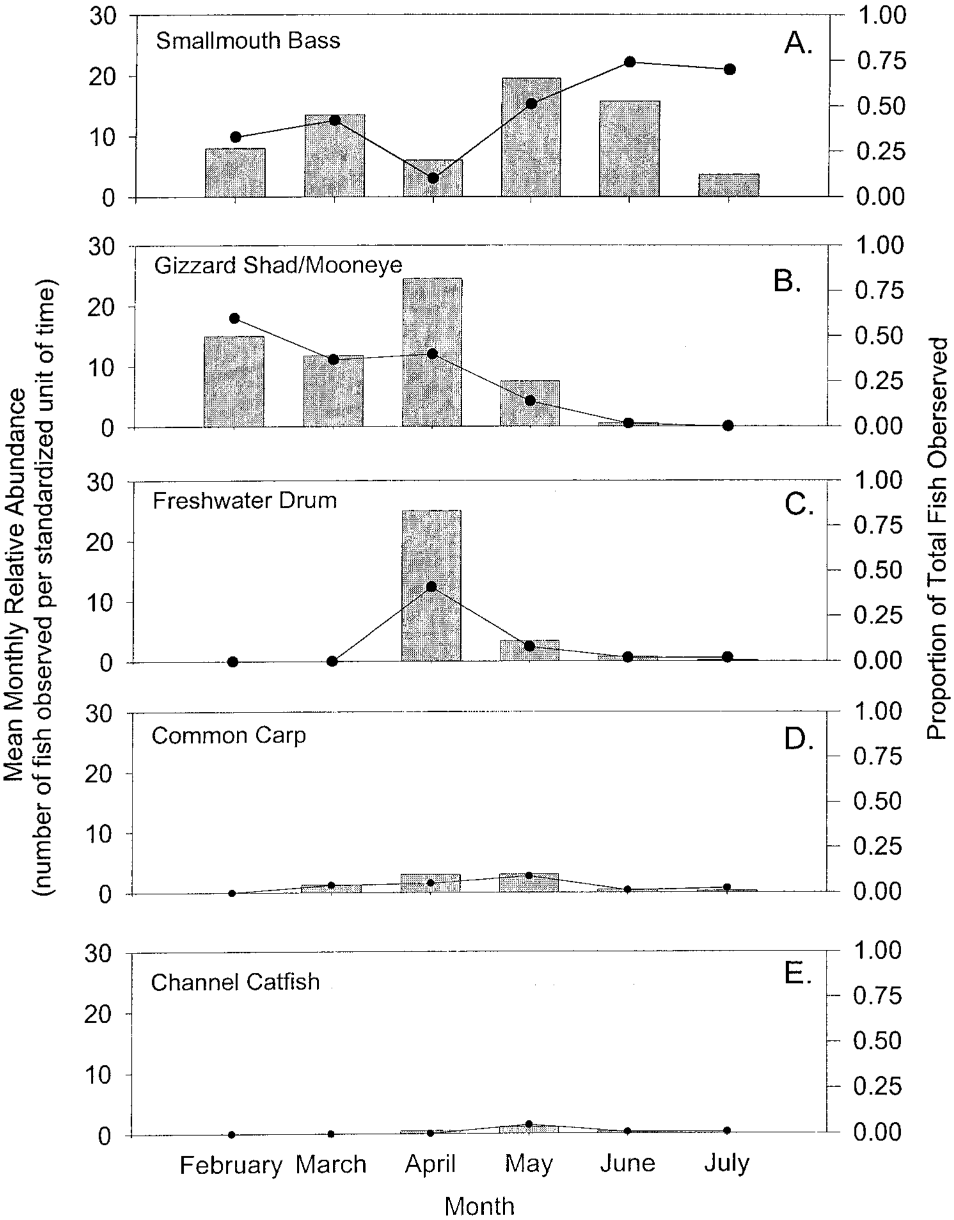

Figure 6. Monthly trends in community structure in the untempered region of the Nanticoke Thermal Generating Station Discharge Canal. Community composition was determined for three ten minute video periods per sampling day. Monthly mean values are plotted (bars) for five species (6A, smallmouth bass; 6B, gizzard shad/mooneye; 6C, freshwater drum; 6D, common carp; 6E, channel catfish) that are either common or economically important. In addition to mean relative abundance, the mean proportion of total fish observed is displayed (scatter and line).

4. Discussion

4.1. Detection efficiencies

Each of the five assessment techniques that we employed would have yielded different discharge residency patterns if used independently. A tenet of all ecological sampling is that the sampling methodologies employed must not bias the sample collected (Krebs, 1989). In practice, approaches that eliminate all biases are limited, resulting in the need to compare different approaches in order to understand the types of biases imparted by different approaches. With this information, it is then possible to apply techniques that minimize sampling biases.

Visual observations were most effective for fish that either congregated just below the surface, or that frequently broke the air water interface to porpoise (i.e., common carp) or to exchange gases for their physostomous swim bladder systems (i.e., longnose gar). Fish that congregated in deep water (i.e., channel catfish) were not observed through the air water interface. Visual observations are inexpensive, and useful for providing anecdotal information, but it is difficult to quantify residency using this approach.

Angling was effective for capturing moderate and large sized piscivores. Several species such as gizzard shad, mooneye, and bait fish species were never captured by angling. These fish prey principally upon zooplankton and other invertebrates. Angling was also ineffective for capturing fish that were present in the canal in very low abundances such as largemouth bass (*Micropterus salmoides*), pumpkinseed, and walleye. Angling has the advantage of permitting the physical examination and enumeration of fish.

The ability of angling to capture fish throughout the season is influenced by the temperature dependence of metabolism, activity, and feeding (Fry, 1947, 1971). At cooler temperatures, fish were less active and in some cases, difficult to capture by angling. During warm water temperatures that were approaching the thermal tolerance of smallmouth bass, we were still able to angle bass even though their abundance was quite low. Angling was most effective however, at intermediate water temperatures (15–20 °C) as has been documented elsewhere (e.g., Elser, 1965).

The modified netting techniques, although unable to detect many species, were effective for capturing specific species for enumeration. Channel catfish could be angled, but were more easily captured using the modified gill nets. Channel catfish are largely a bottom dwelling species and their serrated pectoral and dorsal spines facilitated capture of even the larger individuals in small-mesh twine via entanglement. Although we attempted to 'fish' the net at shallower depths, we captured fish only on the bottom. The modified hoop net was effective for fish that were present in TP1 at high densities. These fish passively entered the net, many of which were also able to swim back out (as observed by exploratory videography). During the colder water temperatures when fish such as smallmouth bass were more difficult to capture by angling, the hoop net proved to be an effective means of passively capturing some species.

Videography detected several species that were not observed using other approaches, in particular, those that were generally rare in the canal including largemouth bass and pumpkinseed. In addition, there were two species that were not detected. Longnose gar were not detected during the study period using videography due to their congregation at the surface. Based upon visual observations prior to the initiation of this study, we placed the camera just below the surface and observed large congregations of longnose gar in the vicinity of TP1. However, at this depth (<1 m), very few other species were observed. During our study, these congregations were also observed visually, but we opted to position the camera at a depth of 3 m (0.5 Z) based upon our preliminary investigations at different depths. The other species not detected with videography was Chinook salmon. This species appeared to be an infrequent resident, and while in the canal, it appeared to orient rheotactically in the main canal flows where we were able to angle them infrequently.

4.2. Community structure

The community structure in the untempered region of the NTGS thermal discharge canal varied on a seasonal basis. The NTGS canal was consistently warmer than Lake water in the vicinity of the station. Species richness and diversity peaked in May with intermediate temperatures. Total abundance of fish peaked in April, but was also high in May. These temperatures and timing coincide with the reproductive activity of many species present in Lake Erie (Scott and Crossman, 1973; Wismer and Christie, 1987). The untempered regions of the discharge canal are void of habitat suitable for spawning and consistent with this we saw no evidence of reproductive activity in this region. However, in the lower reaches of the canal, numerous species spawned in May 1999 including smallmouth bass, longnose gar and white bass. In previous years, these and other species have also been documented to spawn in the lower reaches of the canal (Balesic, 1990; McKinley *et al.*, 2000).

Total abundance, species richness and diversity was lowest during July when water temperatures began to approach the upper levels of both preference and tolerance for many of the fish species in the canal (See Coutant, 1977). Other studies have reported that thermal discharge canals are often void of fish in the summer at extreme temperatures, but do attract fish in large concentrations at other times of the year (e.g., Yoder and Gammon, 1976). The community structure was most even in April as evidenced by values close to 1. During the other months, the evenness value was higher than 1 indicating that the community was comprised of dissimilar species abundances including some rare species and some abundant species.

Throughout the months that we monitored the canal, several species dominated in terms of relative abundance and proportion of total fish observed. These included smallmouth bass, gizzard shad, mooneye, and freshwater drum. Previous telemetric work at NTGS indicated that individual smallmouth bass reside in the untempered regions for extended periods of time in the winter (Cooke *et al.*, 2000). Our videographic results from this study further indicate that smallmouth bass continue to use these regions of the canal until water temperatures rise beyond the thermal preference of smallmouth bass (Approx. 28 °C; Armour, 1993). Similar patterns were observed with gizzard shad and mooneye, with their contribution to relative abundance and proportion of total fish observed decreasing seasonally. Coutant (1975) also found that gizzard shad congregated in a thermal discharge, particularly in the early spring. Gizzard shad are poorly adapted for survival in cold water temperatures (Lewis and Bodensteiner, 1986) and seek warm water refugia such as heated discharges in the winter. In Lake Erie, over-winter gizzard shad mortality has been recognized as a relatively common phenomenon (White *et al.*, 1986). Gizzard shad and mooneye are apparently also particularly sensitive to warm temperatures and avoid temperatures as low as 23.5 and 22 °C, respectively (Gammon, 1971). Interestingly, Yoder and Gammon (1976) reported that gizzard shad avoided an effluent canal in all seasons. We recognize that because gizzard shad and mooneye were indistinguishable by video, it is inappropriate to assume that changes in one were representative of the other.

Freshwater drum were absent during February and March, but comprised nearly 50% of the total number of fish by April. After April, their abundance decreased drastically as the water temperatures approached their avoidance temperatures. This period of high freshwater drum abundance did not coincide with the reproductive phase. Channel catfish and common carp were occasionally observed but they likely spent the majority of their time in the canal in the lower reaches. Previous telemetric studies (Cooke and McKinley, 1999) indicated that carp and catfish residency decreased seasonally. However, Cooke and McKinley (1999), also reported a spike in catfish residency in April, that extended into May, likely due to the rheotactic nature of this species at spawning temperatures.

4.3. VIDEOGRAPHIC APPROACH

We were able to locate only two studies that used videography to assess hydro related impacts excluding fishway monitoring. Gray (1977) used videography in an experimental flume to assess behavioral responses of juvenile Chinook salmon to thermal effluent. Video proved to be an effective approach, although the laboratory setting removed many of the difficulties faced under field conditions. The only field study was executed by Harcus (1991) to monitor fish behaviour and entrapment at a nuclear power plant on Lake Ontario. Harcus deployed three types of video apparatus (mobile ROV submersible camera, stationary camera, and diver handheld camera) from a vessel anchored above the water intake. He concluded that the video systems permitted effective observation of fish behaviour and permitted the identification and enumeration of most species. However, none of the video footage was collected in a standardized location or protocol to permit direct comparisons. Harcus (1991) considered that stationary cameras are limited by a small viewing area from a fixed position thus relying upon chance encounters to observe fish. We agree that for exploration purposes, a fixed camera is not ideal. However, for quantifying and describing community structure in a thermal discharge canal over an extended period of time, a fixed camera provides a standardized location(s) such that seasonal comparisons can be conducted. Researchers must also recognize that when using a standardized camera mount, the size of the sampling area varies over time with factors that influence in-water visibility (e.g., turbidity, surface reflectance, light intensity). For this reason, monitoring appropriate visibility indicators and calibrations become essential components of a fixed mount camera array.

When water temperatures approach the upper limits of a fishes thermal tolerance, they can be more susceptible to stress and mortality from capture and handling. Furthermore, the warm conditions can lead to rapid proliferation of external fungal infections from handling induced epidermal abrasions (i.e., from netting and angling). Sensitive species, fish that are residing in environmentally extreme conditions, or both, require the use of alternative monitoring approaches to minimize injury and mortality (Cooke *et al.*, 1998). Video is a logical tool for these instances.

The two largest problems with using videography are water clarity and light levels. Water clarity issues are impossible to remedy, thus restricting this methodology to water bodies with acceptable levels of turbidity, or to observational days when water clarity is not impaired by suspended sediment or algal blooms. Low light levels are an easier problem to remedy. Improvements in videographic equipment permit the use of cameras designed for low light conditions. Further, infrared light (which is not detected by the fish) can provide additional illumination and aids in generating contrast when using black and white video-cameras (Collins *et al.*, 1991). The use of infrared lighting has been successful for collecting nocturnal data on nest guarding smallmouth bass (Hinch and Collins, 1991).

A further problem with videography is multiple detections of the same individuals. Multiple detections are not relevant if one is attempting to obtain presence/absence data, but may be relevant for assessing relative abundance. We chose the 10 min interval as fish were relatively sedentary and because our field of view was so large. If fish were more mobile or if a field of view was restricted, an approach that involved viewing point in time stills might be more appropriate. A variety of methods can be used to extract data from videography depending upon different sampling constraints as outlined by Altmann (1974).

4.4. Conclusion

In conclusion, our study revealed that fixed underwater videography is a powerful, non-invasive, safe, and cost-effective approach for the assessment of fish community structure in the untempered regions of a thermal discharge canal. Our approach permitted us to monitor the seasonal trends in community structure and to relate these to water temperature conditions. We submit that this approach could be employed in other locations with adequate water clarity. Ideally, videography can be supplemented with other non-invasive approaches such as visual observations, or techniques that result in the capture of fish (i.e., targeted angling, netting) for enumeration. Station operators, managers and regulators could use real time videographic assessments to monitor the response of fish to experimental operating regimes (Balesic, 1990) or to potentially harmful procedures such as the application of biocides to remove biofilm from condenser cooling systems (Dickson *et al.*, 1977). Adaptive decisions based upon real-time behavioural and abundance assays from an array of underwater video cameras positioned throughout a discharge complex could help to minimize morbidity and mortality.

Longer-term post collection analyses are useful for monitoring trends in community composition and residency. Furthermore, additional behavioural information including species interactions and feeding (e.g., Collins and Hinch, 1993), as well as energetic information on swimming activity (Boisclair, 1992; Krohn and Boisclair, 1994; Trudel and Boisclair, 1996) and ventilation rates (Heath, 1973) could be extracted from video. The quantification of these metrics would aid in our understanding of how fish respond to fluctuations in operational and environmental conditions, and the consequences of living in a variable thermal environment. *In situ* field measurements are still rare, with the majority of inferences being derived from laboratory studies that do not incorporate the site-specific conditions experienced by free-swimming fish. Indeed, with the further miniaturization of technology, we will be able to monitor fish activity from animal borne videographic devices similar to those already being developed for marine mammals (e.g., Marshall, 1998).

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