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Ecology of Lake Ontario Brown Trout

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ECOLOGY OF LAKE ONTARIO BROWN TROUT

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by

David C. Nettles

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THESIS DEFENSE

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INTRODUCTION

The Lake Ontario salmonid fishery originally consisted of Atlantic salmon (*Salmo salar*) and lake trout (*Salvelinus namaycush*); however, man's impact on Lake Ontario and its watershed led to the eventual decline of both native species. That impact was seen first in the mid-1800's when Atlantic salmon began to decline in Lake Ontario (Parsons 1973). Dam construction prevented passage of salmon to spawning grounds, deforestation and pollution reduced water quality, and over-fishing diminished numbers. The end result was the extinction of Atlantic salmon in Lake Ontario before 1900 (Parsons 1973; Christie 1973). Similarly, Lake Ontario's lake trout became extinct before 1950. The sea lamprey (*Petromyzon marinus*) played a role in the decline of lake trout, but only after extremely heavy fishing pressure had reduced the abundance and condition of Lake Ontario populations (Christie 1973, 1974).

Attempts to stock salmonids in Lake Ontario began as early as 1866 (Parsons 1973). Until recently, the numerous attempts to establish or re-establish salmonid stocks resulted in very little success (Christie 1973, 1974; Carlson 1973; Great Lakes Basin Commission 1975; St. Lawrence Eastern Ontario Commission 1978). Failed experimental lake trout stockings in the 1950's showed the sea lamprey to be an important factor preventing re-establishment (Christie 1973). Samples of stocked coho and chinook salmon taken by New York in 1971 also showed very high incidences of sea lamprey attacks (St. Lawrence Eastern Ontario Commission 1978).

It was not until the start of heavy salmonid stocking and the Lake Ontario sea lamprey control program in 1971 (Christie 1974; Great Lakes Basin Commission 1975; St. Lawrence Eastern Ontario Commission 1978) that sea lamprey populations were checked at levels conducive to greatly improved salmonid growth and survival. These programs, coupled with pollution control, contributed to habitat improvement and made possible the increasingly successful Lake Ontario salmonid fishery that exists today.

Since the successful introduction of brown trout to Lake Ontario in 1973, stocking levels have steadily increased, ranging from 60,000 (1973) to 754,000 (1982) per year (Kolenosky and Letendre 1983). Largely unsuccessful natural reproduction among south shore Lake Ontario brown trout (Abraham 1980) necessitates stocking on a "put and take" basis to maintain the fishery. Currently, recreational harvests fall far short of their potential (Eckert 1983; Voiland 1982). Insufficient knowledge of fish habitat preferences and location, particularly during the summer months, is partly to blame for the incomplete harvest.

While little was known of summer offshore distribution, Lake Ontario brown trout were known to occupy waters very close to shore in spring and fall, an apparent response to preferred water temperatures (Eckert, personal communication). Similarly, it was thought offshore migration occurred when inshore water temperatures exceeded brown trout preferences with the approach of summer. Fall inshore migrations, prompted by maturing brown trout reproductive condition, resulted in stream entry and efforts to locate and spawn in suitable habitat.

Previous brown trout telemetry studies have examined periods of fall inshore migration and stream entry in relation to lake and/or stream environmental factors on Lake Erie (Wenger 1982), homing tendencies on Lake Superior (Winter 1976), and day/night, offshore/inshore activities in Arthrey Loch, Scotland (Young et al. 1972; Oswald 1978). Previous summer netting studies have examined salmonid vertical positioning within the water column of Lake Erie (Lichorat 1982) and brown trout temperature preferences, food preferences, and bottom associations in Lake Ontario (Abraham 1979). Additional New York State Department of Environmental Conservation (DEC) Lake Ontario studies have collected data concerning brown trout population abundance, survival, distribution, age frequency, biological characteristics, and incidence of sea lamprey attacks (Eckert 1983). Lake Ontario sport fishery statistics have also been compiled through direct contact creel surveys (Panek 1981) and angler diaries (Abraham 1983).

The purpose of my study was to examine seasonal movements, behavior, and habitat preferences of brown trout (*Salmo trutta*) in Lake Ontario. During fall 1980 and spring and fall 1981, the activities of 36 radio-tagged brown trout were monitored near the southern shore of Lake Ontario between Port Bay and Point Breeze (Fig. 1). Underwater radio telemetry techniques were utilized to evaluate inshore and offshore periods of occupancy, range of movements, attraction to outflow areas, depth and temperature preferences, spawning success, and homing to original stocking sites. The use of internal (surgical) and external radio-tag attachment permitted a comparison of methods. In conjunction with telemetry, vertical gill netting was used to evaluate brown trout location, depth and temperature distributions, and food preference during the summers of 1981 and 1982.

Proximity to SUNY Brockport and nearby marina and storage facilities

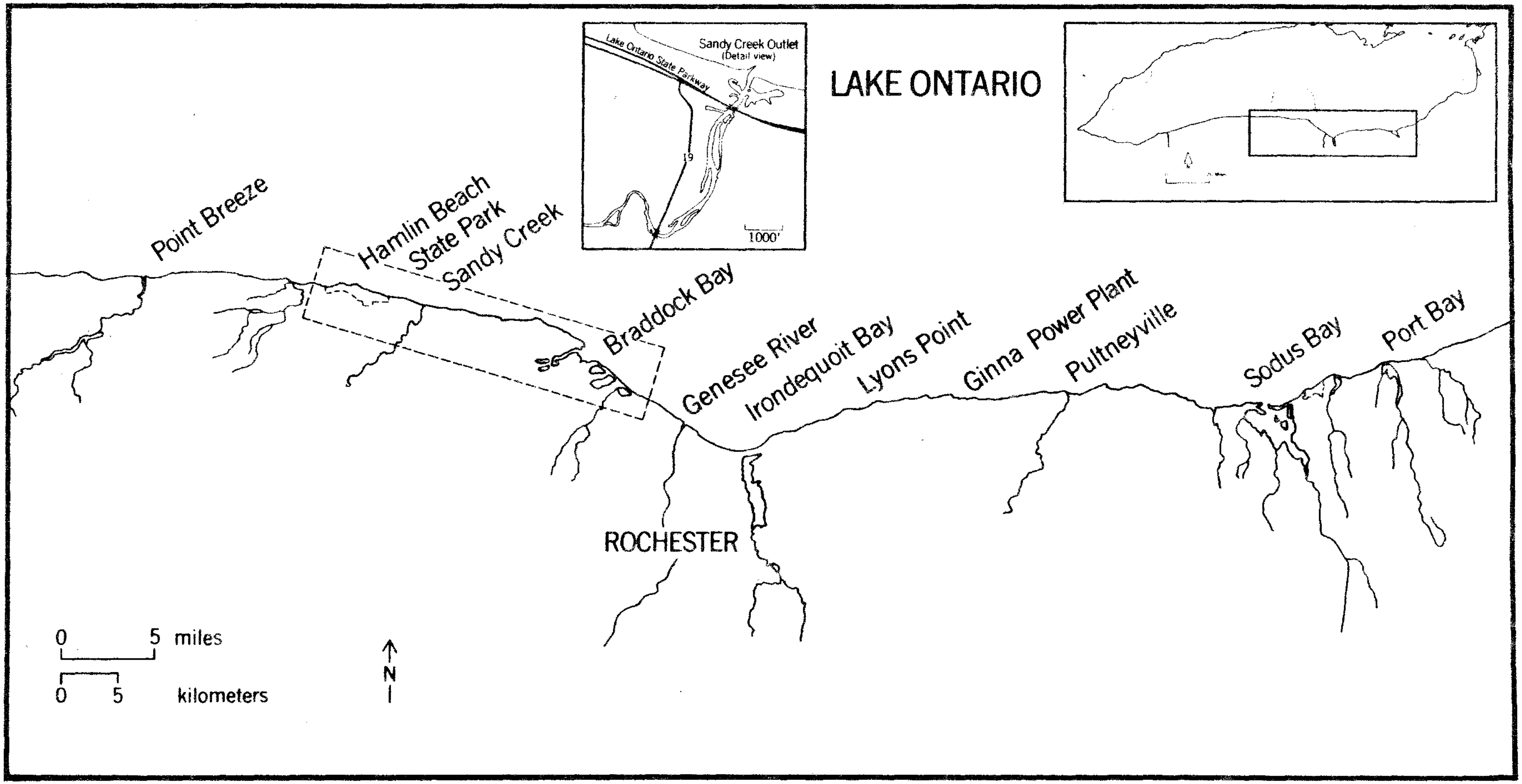


Fig. 1. **The study area.** Inserts show the capture/release site at Sandy Creek and the study area in relation to Lake Ontario. The dashed rectangle represents the limited tracking area of fall 1980.

made Sandy Creek (Monroe Co., N.Y.) a convenient base of operations (see Fig. 1). In addition, fish capture was enhanced by considerable numbers of salmonids which could be found in and near the creek mouth in spring and fall. Sandy Creek is characterized by riffle pool habitat over most of its upstream length, which contrasts with the lower 1.2km where current slows in a drowned river mouth and wetlands predominate. Agricultural lands dominate the watershed, though minor industry and residential areas are also present. Potential salmonid spawning habitat exists in spring and fall but high creek temperatures in summer exceed salmonid thermal maxima of 24-28°C depending upon species (Scott and Crossman 1972; Needham 1938).

The lakeshore is typical of the western basin of Lake Ontario with numerous small tributaries, scattered wetlands and embayments, and considerable human development, particularly near larger tributaries. Very little substrate structure exists in the western basin where inshore sand and/or cobble substrate gives way to mud on a gently sloping bottom reaching depths in excess of 240m.

Unlike previous studies, combined spring, summer, and fall data provide a comprehensive look at seasonal movements, behavior, and habitat preferences of Lake Ontario brown trout. My thesis will attempt to integrate this and other studies to define the ecology of brown trout in Lake Ontario.

MATERIALS AND METHODS

Radio telemetry equipment used in this study was designed and built by the Cedar Creek Bioelectronics Laboratory, University of Minnesota (Winter 1976; Haynes 1978; Winter et al. 1978). Radio receivers operated on a carrier frequency of 53Mhz and were capable of distinguishing over 100 separately identifiable crystal-tuned transmitters. Cylindrical transmitters were encased in epoxy to provide waterproofing. Signal transmission was enhanced by antennae which projected from the rear of the transmitters. Surgically attached transmitters were approximately 2.0cm in diameter, varied in length from 5.0 to 7.0cm (antenna excluded), and weighed 16.1-20.5g in water, depending upon battery size. Externally attached transmitters were of uniform size (2.0cm in diameter, 8.3cm long and weighed approximately 26g in water). Smaller fish received smaller transmitters which did not exceed 2% of fish body weight, a criterion used by Gray and Haynes (1979). A life of 6 to 8 months was expected, though battery life exceeded a year in some cases.

In addition to providing location information, 30 of the 36 transmitters were temperature sensing (fall 1980, spring 1981). Individual temperature sensitive transmitters were calibrated by equilibrating them in water in a controlled temperature environmental chamber and recording transmitter pulse rates at 2°C intervals between 4 and 28°C. As temperatures rose, pulse rates quickened. A graph relating pulse rates to temperature was constructed to enable quick temperature conversions from field data (Haynes 1978).

Capture of brown trout was limited to Sandy Creek and the shallow areas of Lake Ontario near the creek mouth. A 6.1-m pontoon boat outfitted with direct current electroshocking gear was used to temporarily stun fish, allowing capture with dip nets. The habits of brown trout in late spring and early fall made nighttime fish capture more productive than comparable attempts during daylight. In early spring and late fall, fish capture became equally productive during the day. Fish were placed in an aerated holding tank, assessed for health, and either retained for radio tagging or rejected and released. Lamprey wounds accounted for the majority of rejections. Brown trout selected for tagging were placed in a 200-liter tank to which a Tricainemethanesulfonate (MS-222) - Quinaldine anesthetic mixture was added. Immobilized fish were measured, weighed, and sexed by external features (when possible) and tagged with a transmitter and plastic anchor tag (Floy Tag Co.). Anchor tags permitted identification of study fish if radio transmitters were internal or lost. Both anchor tags and radio tags were numbered and addressed in the hope of obtaining capture information and transmitter return if fish were caught by anglers.

Transmitters were attached to fish using two methods: external (Haynes 1978; Wenger 1982) and surgical implantation into the body cavity (Winter et al. 1978; Stasko and Pincock 1977). External radio-tag attachment was used for 8 brown trout in fall 1980; surgical implantation was used for 22 spring and 6 fall brown trout in 1981.

External transmitters were equipped with 3 teflon-coated wires, 2 neoprene rubber pads, and a plastic plate (Fig. 2). Transmitter attachment was accomplished using a postmortem needle to thread the wires through one rubber pad, through the dorsal musculature beneath

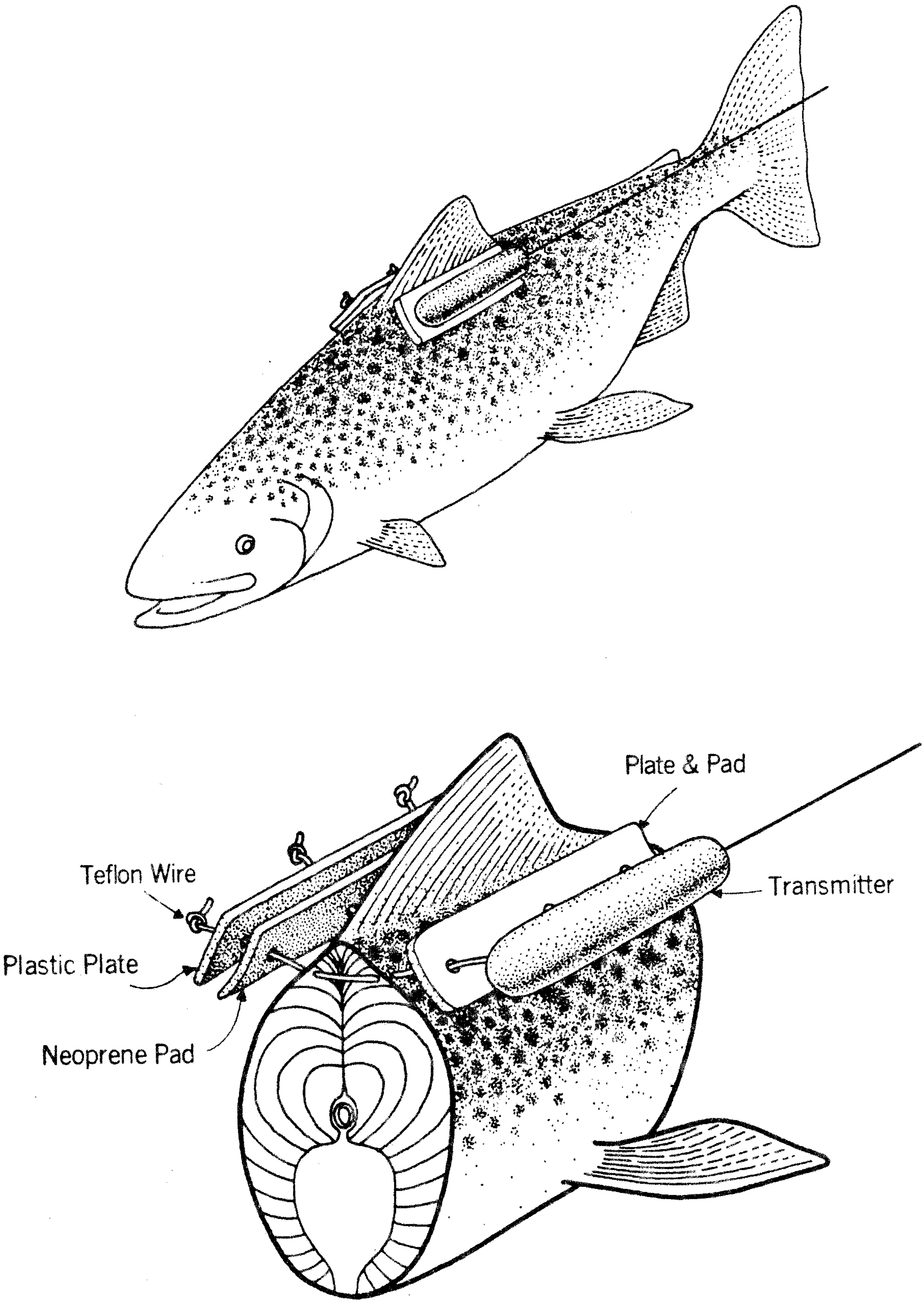


Fig. 2. External transmitter attachment.

the dorsal fin, through the second rubber pad, and finally through the plastic plate against which the wires were firmly knotted. Note that the wires did not penetrate the major lateral muscle masses. The padded plates provided soft surfaces which minimized abrasion at the attachment site. A rigid whip antenna trailed dorsolaterally.

Internal transmitters were smooth cylinders with limp antennae and lacked external attachment structures described above. These transmitters were surgically implanted into the body cavity, antenna first, through a 3 to 4-cm long incision made forward of the pelvic fins (Fig. 3). This area of the body cavity more easily accepts a transmitter without excessive crowding of internal organs. Incisions were closed with a surgeons needle and 6-lb monofilament fishing line sutures. Malachite green was applied to attachment wounds as a disinfectant. Surgical instruments and internal transmitters were sterilized in a Zephiran Chloride solution before surgery.

Externally tagged brown trout were returned to the vicinity of capture after demonstrating upright posture and active swimming ability. Surgically tagged brown trout were placed in submerged cages and held for observation up to 24 hours before release.

Fish movements after release were monitored by day and/or night as dictated by tracking success. Radio tracking was conducted by boat, airplane, truck, and hand-held receiving gear (Winter *et al.* 1978). Directional yagi antennae were mounted to facilitate 360° rotation on 4.3 and 7.5-m boats and on a pick-up truck for shoreline tracking. Two loop antennae were attached to the wing struts of an airplane to enable radio tracking over long distances. Loop antennae were arrayed perpendicularly to each other on opposite wing struts to insure maximum signal

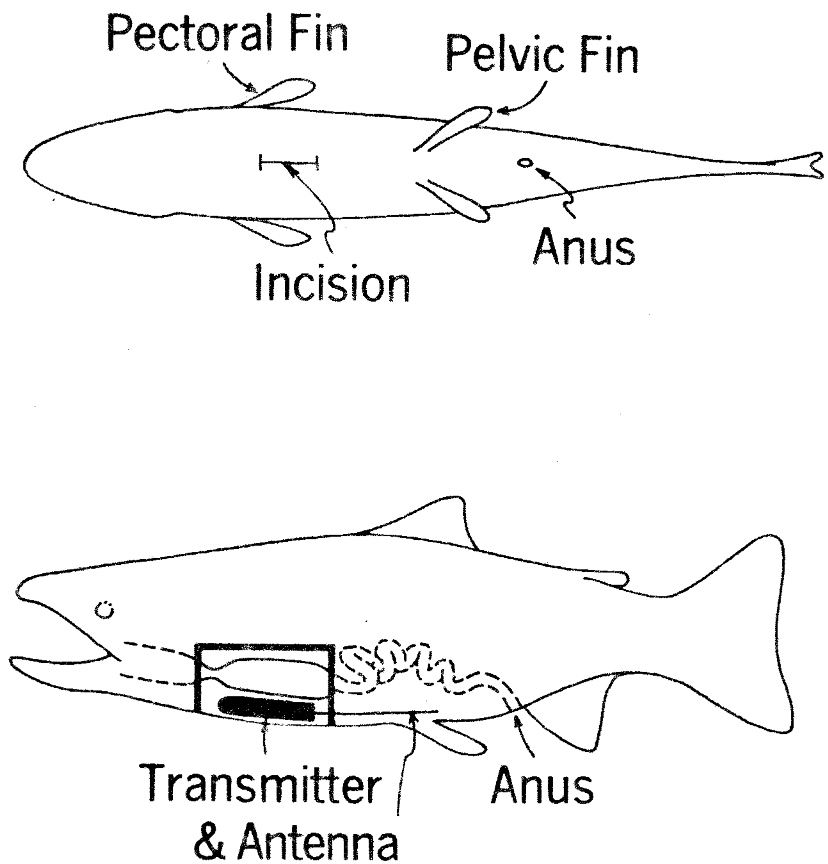


Fig. 3. Surgical transmitter attachment.

reception in all directions. Occasional tracking by foot with a hand-held loop antenna was used to monitor otherwise inaccessible sections of streams. Manually tuned receivers were used for all tracking operations except airplane flights, where automatic frequency scanning receivers were necessary due to air speed and numbers of fish.

Depending on water conductivity (salinity), radio signals attenuate with depth (Winter et al. 1978), thus limiting the reception range of radio signals. Tests on Lake Ontario showed the maximum depth of radio signal reception to be 14-15m under ideally controlled conditions. Because the depth of Lake Ontario exceeds 240m, contact with radio-tagged brown trout was limited to times when fish occupied the upper portion of the water column or shallow nearshore water in spring and fall.

Tracking in fall 1980 was generally confined to the area of shoreline within the dashed rectangle of Figure 1. Tracking operations were expanded in 1981 using aircraft capable of long-distance tracking. Airplane and boat searches were conducted parallel to the shoreline until either all radio-tagged fish were found or a pre-set search pattern was completed. Search patterns varied in distance from shore and location according to fish movements and tracking method.

Local tracking (Genesee River to Point Breeze) for ragio-tagged brown trout was conducted primarily by boat or truck, depending on wave and weather conditions. When tracking by boat or truck, listening stations approximately 1km apart were established where possible along shore. These relatively short tracking intervals were maintained to maximize the probability of signal reception from tagged fish. When conditions were ideal (e.g. transmitter very close to the surface, no radio interference, no electrical obstructions between the transmitter and receiver), the maximum range of reception was approximately 4.0km when tracking on the surface but approached 10.0km when tracking by airplane. Airplane tracking was generally reserved for lost fish searches or for tracking fish known to have moved beyond the local tracking area, though local areas were also monitored during flights. Upon encountering radio-tagged fish, locations determined from the direction and strength of the signal (Haynes 1978) and temperatures (when applicable) were recorded. Daily tracking was conducted as often as possible. Airplane tracking operations were conducted 2-3 times a week. As numbers of fish remaining within tracking range diminished due to offshore movement, tracking effort was reduced accordingly.

Locations of radio-tagged brown trout in Lake Ontario were plotted on track maps. The shoreline was proportionally straightened to a linear scale for simpler presentation. Points of contact (c.f. Fig. 5) were then connected in chronological order to show individual fish movement patterns. Linear distances traveled by individual fish were analyzed for range, distance traveled during successive daily tracking intervals, and overall distance traveled during a study period.

Hatchery fin clips indicated where study fish were stocked, permitting evaluation of fall brown trout homing tendencies. Brown trout location data was also compared to water temperature, turbidity, current, and proximity to outflow areas. Daily water temperatures and turbidity levels were obtained from the Brockport Water Treatment Plant (Tom Clark, personal communication) located 2km west of Sandy Creek. Water temperatures were also obtained from Rochester Gas and Electric's Russel Station and Ginna Nuclear Power Station (David Dakin, personal communication) which are located 25 and 53km east, respectively, of Sandy Creek.

All three water intakes were located approximately 1km offshore at depths of 7-8m and provided standard sites from which comparable water temperatures were obtained. Daily average intake water temperatures, coupled with temperatures transmitted from fish, were used to determine temperature ranges when brown trout occupied nearshore regions of Lake Ontario.

Lake Ontario vertical gill netting studies were conducted during the summers of 1981 and 1982. Vertical gill net panels (11.4 and 14.0-cm stretch mesh) were 15m long and 5m wide. Nets were set at various locations between Hamlin Beach State Park and Braddock Bay at distances up to 23km from shore. A 7.5-m boat was used to suspend vertical gill nets from floats in a manner designed to fish a vertical section of water column from the surface to bottom to a maximum depth of 47m (Fig. 4). Up to 5 individually suspended groups of vertical net (usually 3) were set at the same time and location. Standard surface to bottom netting depths were 17, 32, and 47m in 1981. In 1982 standard netting depths were expanded to include 30 and 45-m sets over depths of 80, 110, and 140m (approximately 8, 16, and 23km offshore).

Horizontal nets set on the bottom (91m long, 14.0-cm stretch mesh) were used to sample the bottom 2m to preserve vertical nets from possible entanglement and damage in 1981. This required using a correction factor (0.114) to compensate for the larger fishing area per meter of depth compared to vertical nets. To avoid this complication in 1982, easily detachable 2m long, 5m wide, 11.4-cm stretch mesh vertical bottom panels were used to eliminate horizontal net conversions and excessive fish captures.

Vertical nets were successfully set during stratified water column

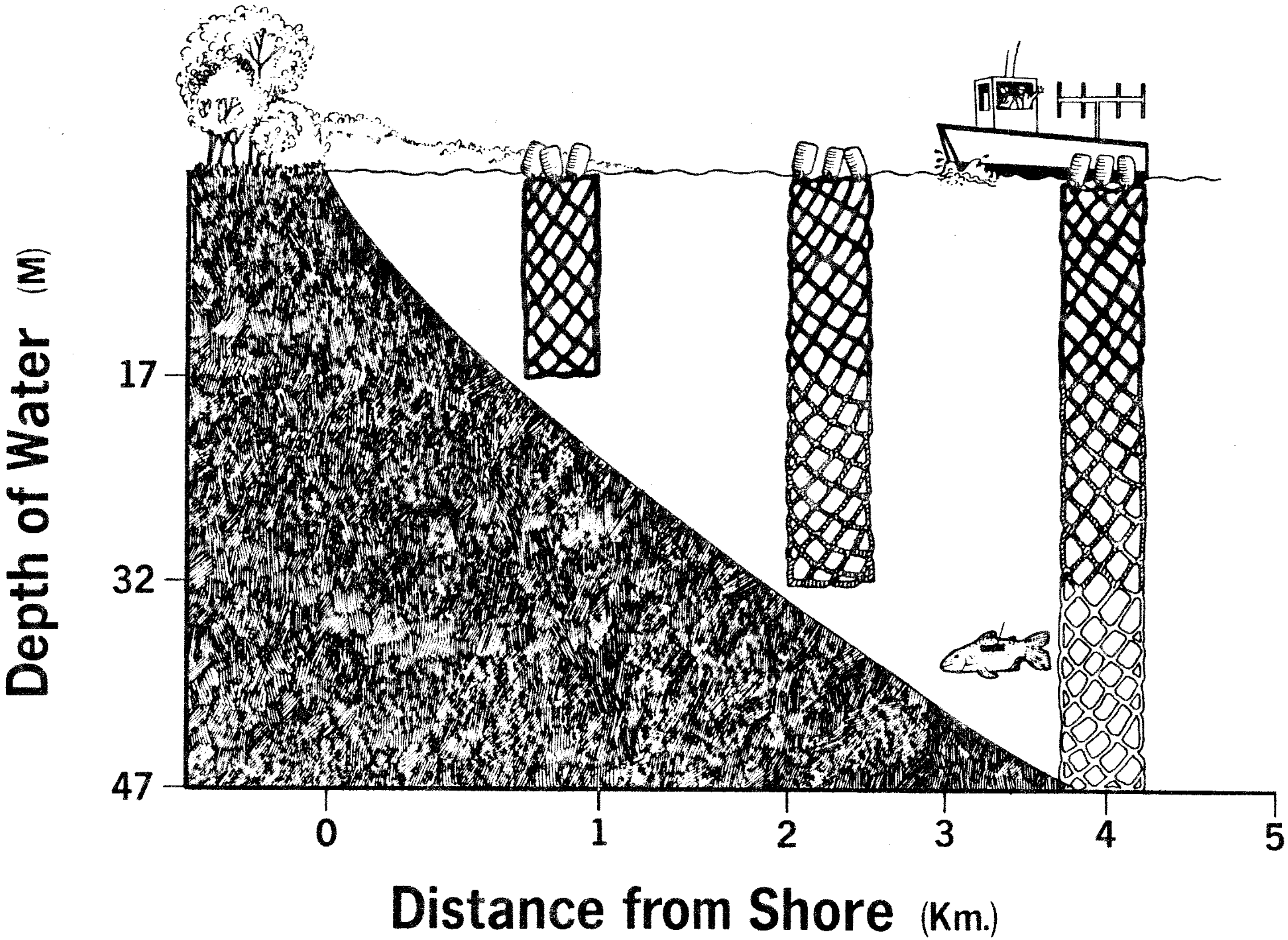


Fig. 4. A representation of vertical gill net suspensions.

conditions an average of 2.7 times per week (27 times total) during the period July 1 to September 7, 1981, and 1.9 times per week (20 times total) from July 1 to September 7, 1982. In 1981 nets were set in the evening and retrieved the following morning, thus catches primarily represented nocturnal fish positions. In 1982 nets were set for approximately 24 hours to eliminate possible day/night biases.

The zone of rapid vertical temperature change, as determined from temperature profiles taken at the beginning and/or conclusion of each sampling period, was often a determining factor in the placement of nets. This zone, hereafter referred to as the "thermoclinal zone", is defined as a portion of the water column where temperatures change by at least $1^{\circ}C$ per meter of depth, a definition used by Lagler (1952) to describe the thermocline. More recent definitions (Wetzel 1975; Cole 1979) place this zone within the metalimnion where $1^{\circ}C$ or greater temperature changes per meter occur. Defining this restricted zone will more precisely convey brown trout preferred habitat information. When two temperature profiles were available for a single daily sampling period, temperature values were averaged (the thermocline often "rocked" several meters in a 24-hour period) for each meter of depth and used for analyses. Temperatures were assigned to fish based upon their depths of capture.

Summer netting data was analyzed in reference to depth of capture, temperature preference, and fish position above bottom and relative to the thermoclinal zone. Length, weight, sex, physical condition, and stomach contents were recorded for all captured brown trout.

Unequal sampling effort at standard netting depths necessitated catch per unit effort (CPUE) conversions. For example:

net area fished	standard netting depth
$100m^2$	17m
$200m^2$	32m

Catch data for the 17m depth would be adjusted by a factor of $200m^2/100m^2 = 2$, because twice the effort was expended at 32m.

Those portions of net that fished 4°C water were not included in CPUE conversions because, despite substantial netting effort in 4°C water, no brown trout were caught in this temperature region. Catch data from disturbed nets (moved or sunk by wind and current) was also deleted.

Stomach contents were examined to define brown trout food preferences. Individual brown trout stomach contents were recorded according to forage species and volume (by displacement) and converted to percentages. Summing and averaging over a whole season provided relative importance values for each species in the brown trout diet. In addition to summer vertical net sampling, nearshore horizontal netting from April 2 to June 22, 1982, provided brown trout stomachs for analysis of spring forage preferences.

RESULTS AND DISCUSSION

General movements and areas of preference of fall radio-tagged brown trout

Fall Lake Ontario radio telemetry studies examined pre-spawning (lake), spawning (stream), and post-spawning (lake) movements of brown trout. Contact was maintained with active radio-tagged brown trout from September 20 to November 24, 1980, and September 22 to December 4, 1981. Successive fall brown trout locations, as determined by radio telemetry, were plotted on track maps to show inshore movements in Lake Ontario (see Figs. 5,8,9,10,15 and Appendix 1). Vertical distances of the tracking lines from the linear shore are not indicative of actual fish distances from shore. Eight fall 1980 radio-tagged brown trout were tracked in the lake for periods ranging from 1 to 27 days. In fall 1981, however, 3 of 6 fish were tracked for 2 to 70 days in the lake, while the others died in Sandy Creek or disappeared immediately after leaving Sandy Creek. Biological data and stocking location information for individual fall radio-tagged brown trout are listed in Table 1.

Typical of fall radio-tagged brown trout was initial eastward movement upon re-entering the lake (7 of 11 fish), and an east/west reversal pattern of movement (8 of 11 fish). Both patterns were illustrated by fish 110 (transmitter frequency) (Fig. 5). This fish also exhibited the longest total movement of fall study fish, traveling a minimum of 163km in 1980 (determined by summing point to point distances). Movements of fall radio-tagged brown trout were typically short with most fish remaining in local nearshore areas east and west of the

Table 1. Biological and stocking site information for fall radio-tagged brown trout.

Fall 1980

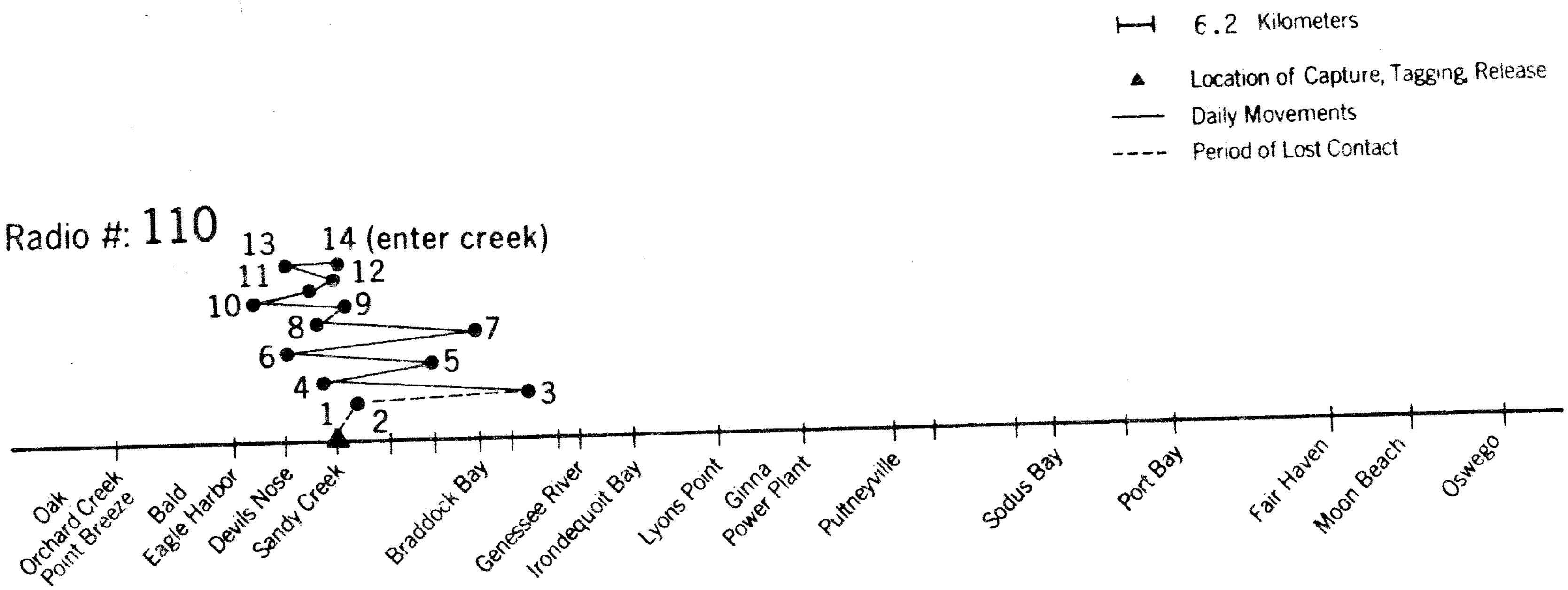
Radio tag frequency	Length (cm)	Weight (kg)	Sex	Hatchery clips	Age[1]	Stocking site
110	59.7	2.9	Female	AD-LV	II+	Hamlin Beach
270	53.3	3.0	Female	-	II+	?
320A	57.2	2.5	Female	-	II+	?
170	61.0	3.2	Male	AD-LV	II+	Hamlin Beach
340A	52.1	2.3	Female	AD-LV	II+	Hamlin Beach
290	67.3	5.1	Female	-	III+	?
210A	59.2	3.2	Male	AD-LV	II+	Hamlin Beach
210B	61.0	3.6	Female	AD regen	II+	Sodus/Oak Orchard[2]

Fall 1981

Radio tag frequency	Length (cm)	Weight (kg)	Sex	Hatchery clips	Age[1]	Stocking site
320B	55.1	2.5	Male	AD	II+	Rochester-Hamlin
340B	51.4	1.8	Female	-	II+	?
470	66.3	4.3	Male	AD	III+	Sodus/Rochester
440	55.0	3.0	Female	-	II+	?
280	60.4	3.4	Male	AD	II+	Rochester-Hamlin
360	64.2	3.4	Male	-	II+	?

[1]Age was determined from length/weight comparisons with Lake Ontario brown trout data from Eckert (1983).

[2]This stocking site is unlikely since 210B exhibited preference for the Hamlin Beach area. Natural fin damage is a possible explanation.



Location	Dates
▲	9/20/80
1	9/20/80
2	9/22/80
3	10/1/80
4	10/2/80
5	10/3/80
6	10/4/80
7	10/5/80
8	10/6/80
9	10/8/80
10	10/9/80
11	10/10/80
12	10/13/80
13	10/13/80 → 10/16/80
14	10/21/80 → 11/8/80 Dead (caught twice by snaggers)

Fig. 5. Radio-tagged brown trout 110 fall lake movements.

capture/release site (10 of 11 fish). Ranges and total movement distances by fall radio-tagged brown trout are displayed in Figure 6.

To examine whether homing behavior played a role in the limited range of movements observed for fall brown trout, length and weight were compared to NYSDEC brown trout assessment data (Eckert 1983) to establish the ages of radio-tagged fish. Stocking sites could then be identified for hatchery fin-clipped, radio-tagged brown trout (see Table 1). Areas preferred by fall radio-tagged brown trout are shown in Figure 7 and compared with original stocking locations. Preferred areas were defined by assigning "preference points" to fish which remained in waters corresponding to 8-km areas of shoreline for three or more consecutive tracking operations. Note that fall 1980 radio-tagged brown trout preferred the Devil's Nose (Hamlin Beach State Park) area and the largest nearby tributary (Sandy Creek). Note also that 4 of 8 radio-tagged brown trout were stocked at Hamlin Beach (Table 1). Fish 210A was repeatedly located directly off its original stocking site (Fig. 8). In 1981, preferred areas were again near original stocking sites for 2 of the 3 radio-tagged brown trout which were tracked in the lake. Fish 280, stocked at 1 of 3 locations (Hamlin Beach, Braddock Bay, or Genesee River), clearly preferred the nearshore area just west of Russel Station (Fig. 9), near the Genesee River. Fish 470, though initially deviating from its original stocking location and showing preference for areas extending from Sandy Creek to the Genesee River, was last observed near its probable stocking location at Sodus Bay on December 4, 1981 (Fig. 10).

Homing behavior was probably the dominant factor in the prevalence of localized east/west reversals which in most cases corresponded to

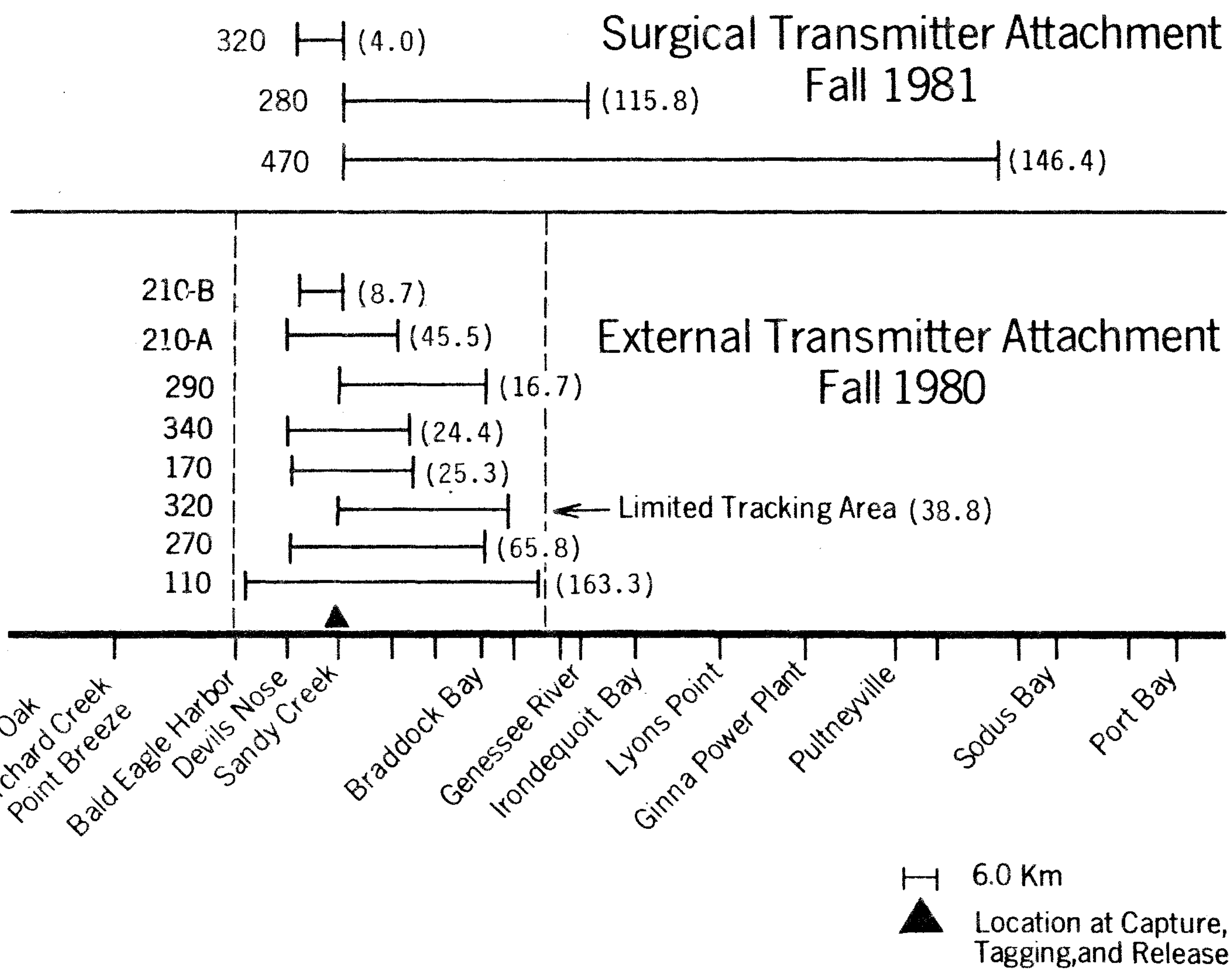


Fig. 6. Range of movements (total km moved) of fall radio-tagged Lake Ontario brown trout.

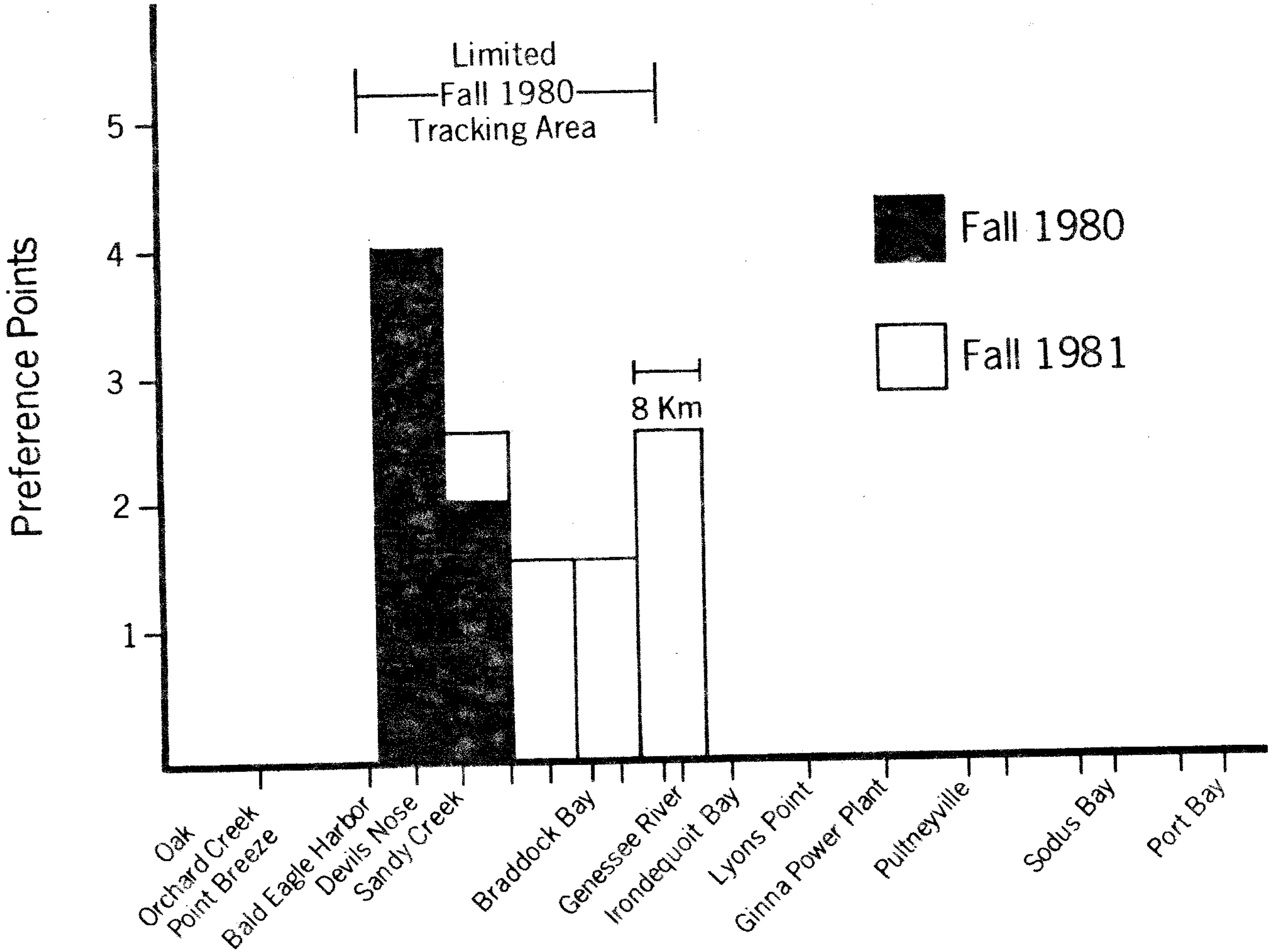
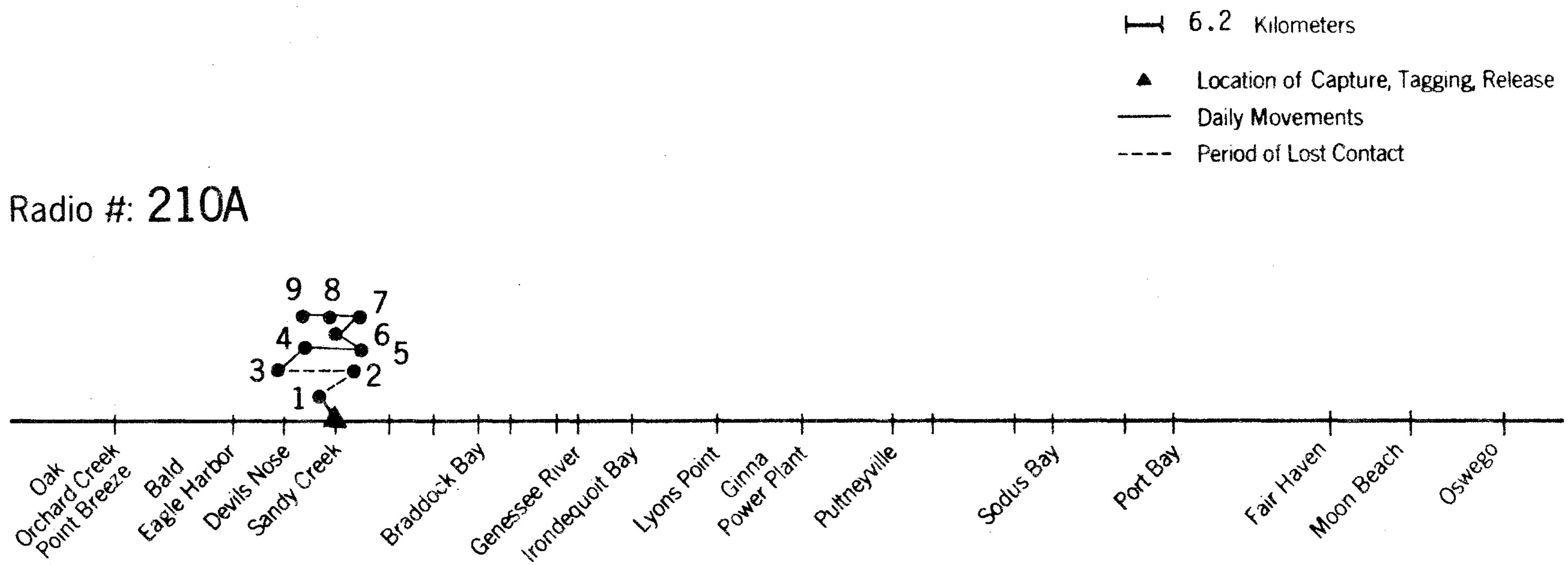
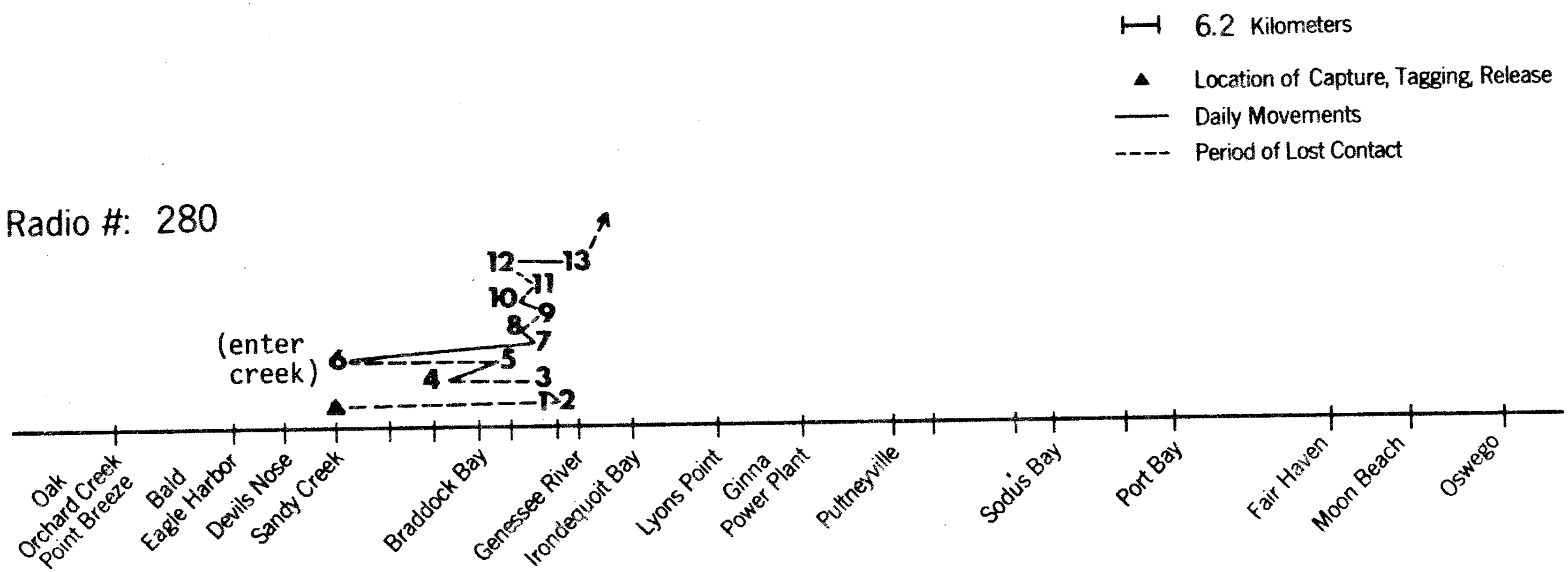


Fig. 7. **Fall preferred areas.** Preference points were assigned to 8km areas where tagged fish were found during three or more successive tracking operations.



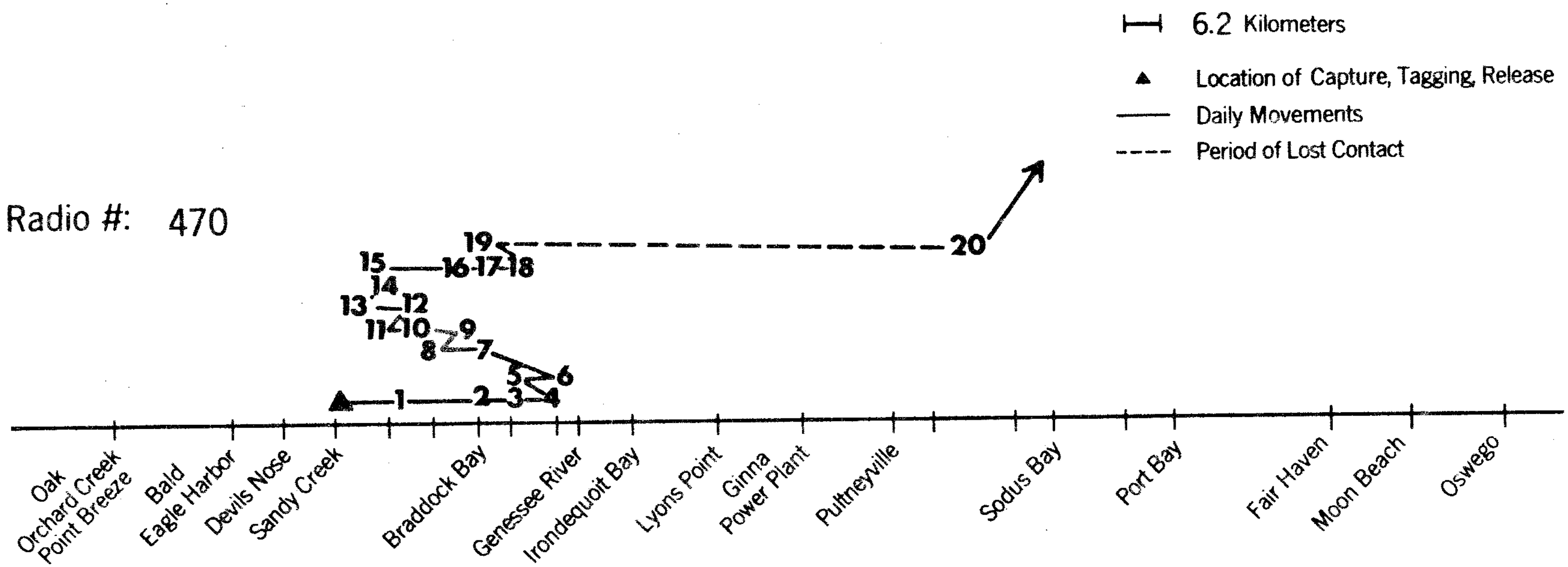
Location	Dates
▲	9/19/80
1	9/20/80
2	9/21/80
3	10/5/80
4	10/6/80 → 10/7/80
5	10/8/80 → 10/13/80
6	10/14/80
7	10/15/80
8	10/16/80
9	10/17/80 → 10/18/80 (caught by angler-line entangled in tag)

Fig. 8. Radio-tagged brown trout 210A fall lake movements.



Location	Dates	Location	Dates
▲	9/28→10/5/81	8	10/23/81
1	10/8/81	9	10/26/81
2	10/9/81	10	10/27→10/28/81
3	10/10/81	11	10/31/81
4	10/13/81	12	11/3→11/5/81
5	10/14/81	13	11/8/81
6	10/19→10/21/81		
7	10/22/81		

Fig. 9. Radio-tagged brown trout 280 fall lake movements.



Location	Dates				
▲	9/25/82	7	10/22/81	14	11/4/81
1	9/26/81	8	10/23/81	15	11/5/81
2	9/27/81	9	10/24→10/27/81	16	11/7/81
3	10/3/81	10	10/28/81	17	11/10/81
4	10/4/81	11	10/30→11/1/81	18	11/12/81
5	10/5/81	12	11/2/81	19	11/13→11/19/81
6	10/9→10/21/81	13	11/3/81	20	12/4/81

Fig. 10. Radio-tagged brown trout 470 fall lake movements.

known original stocking locations. Wenger (1982) and Winter (1976) report similar homing behavior for brown trout in Lakes Erie and Superior, respectively. Initial eastward movement may be attributed to brown trout moving with the predominant eastward current along the south central shore of Lake Ontario (International Field Year for the Great Lakes 1980).

Aside from preference for original stocking locations, attraction to the Russel Power Station (hashmark immediately west of Genesee River) warm water discharge was apparent in fish 280 and 470 in fall 1981 (see Figs. 9 and 10). Unfortunately, these fish were not equipped with temperature sensing transmitters, so ambient water temperature changes could not be monitored. Fish 280 spent 6 days near the western fringe of the discharge plume. Similarly, fish 470 interrupted movements along shore and spent 11 days in and near the warm water plume. As the discharge tributary is unsuitable brown trout spawning habitat (high temperatures and poor substrate) and no brown trout are known to be stocked at that point, attraction to the discharge is probably unrelated to homing or spawning influences. I suggest that the contrasting temperatures of the warm water plume and the cooler lake water provide an attraction for brown trout and possibly their forage fish. Possible reasons for such behavior are discussed in later sections.

Fall movement differences among tagging methods and brown trout sexes

In an effort to determine if male and female brown trout exhibited different movements, day-to-day (approximately 24 hours) movements of individual fish were converted to kmh^{-1} to calculate swimming speed (see Table 2). This was done to eliminate, as much as possible,

Table 2. Fall radio-tagged brown trout day-to-day distances traveled converted to kmh^{-1}.

Fall 1980

Sex	Transmitter frequency	Movement rate (kmh^{-1})
Male	210A	.32, .14, .11, .13, .18, .17
Male	170	.05, .75
Female	320A	.53
Female	270	.80, .96
Female	110	.93, .69, .76, .70, .71, .56, .31, .20

Fall 1981

Sex	Transmitter frequency	Movement rate (kmh^{-1})
Male	470	.32, .30, .15, .08, .29, .16, .20, .14, .26, .10, .07, .21
Male	280	.05, .05, .26, .15, .11

unobserved movements over longer tracking intervals. Unfortunately, there were no female fish in 1981 to provide data for comparisons. A t-test between males showed that surgically tagged fall 1981 and externally tagged fall 1980 fish did not differ significantly ($p=0.48$) in day-to-day movement rates, indicating that possible behavioral differences between tagging methods probably did not affect swimming speed. Though Mellas (1982) and McCormack (1980) report a significant reduction in swimming stamina for externally radio-tagged rainbow trout exposed to high current velocities, such does not appear to be the case for brown trout in the lentic Lake Ontario environment. The most rapid fall movement rate (.96kmh^{-1}, 22.6kmday^{-1}) was exhibited by an externally tagged female. A t-test was used to compare all fall male brown trout movements with 1980 female brown trout movements. Females were found to move significantly faster and to travel greater distances during day-to-day tracking intervals than did males ($p=0.0001$). It appears that female brown trout are typically more active than male brown trout during fall nearshore movements associated with reproductive behavior.

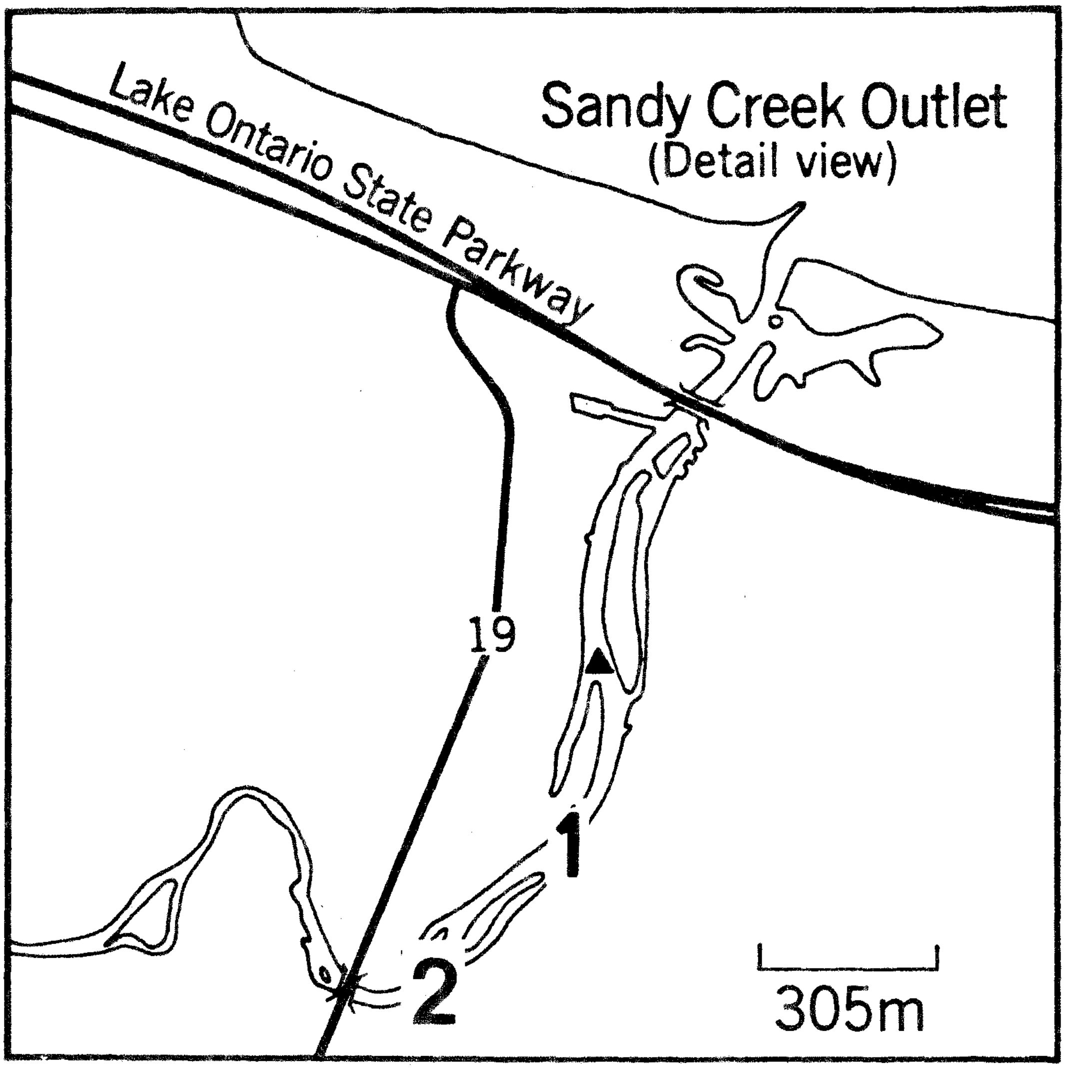
Brown trout reproductive success

Fall radio-tagged brown trout movements were also monitored in Sandy Creek in an effort to determine the likelihood of reproductive success. Six of 14 brown trout engaged in stream movements before returning to Lake Ontario (Figs. 11,14,16; Appendix 3). No radio-tagged brown trout were observed to move far enough upstream to reach habitat suitable for reproductive success. Any radio-tagged brown trout spawning that may have occurred (none was directly observed due to depth and turbidity of the water) was confined to the lower 1.2km of stream where mud substrate most certainly prevented survival of eggs. The furthest upstream migration was recorded for fish 210B which stopped just short of potential spawning areas which begin with riffle-pool sequences above the Route 19 bridge crossing (Fig. 11). No entries into other creeks by fall radio-tagged brown trout were observed. Wenger (1982), however, reports active upstream migration and probable spawning (not observed) by radio-tagged brown trout in Lake Erie tributaries. There is also evidence for anadromous brown trout spawning populations in Canadian tributaries of Lake Ontario (R. Desjardine, personal communication) and in some eastern Lake Ontario tributaries of New York, but the spawning potential of most New York tributaries does not appear to be taken advantage of by Lake Ontario brown trout (Abraham 1980). No juvenile brown trout have been observed in repeated upstream electroshocking efforts in Sandy Creek (Haynes, personal communication).

Factors influencing fall inshore/offshore movements

Stream and lake capture of brown trout in early fall when lake temperatures were relatively high was considerably enhanced when electroshocking was done at night. Increased brown trout captures indicated that larger numbers of brown trout occupied the stream and nearby lake waters at night. This was not the case in early spring when waters were cold, as fish capture success was roughly equal day and night. This indicates an apparent light sensitivity by brown trout at least when water temperatures are at the upper end of their preferred temperature range in Lake Ontario, or when brown trout are approaching spawning condition. Apparently, early fall stream entries and occupancy are enhanced at night.

Radio #: 210 B



Location:	Date:
▲	11/8/80
1	11/9/80
2	11/10/80

Fig. 11. Radio-tagged brown trout 210B fall creek movements.

Oswald (1978) and Young et al. (1972) report brown trout behavior of a similar nature in Arthrey Loch, a shallow (6m maximum depth) 24-acre lake in Scotland. Brown trout equipped with ultrasonic transmitters were typically found to occupy deeper offshore waters during the day and shallower nearshore waters at night. However, this behavior was not reported to be a fall seasonal occurrence. Light intensity was the suggested deterrent to daytime feeding and shallow water presence of brown trout. Young et al. and Oswald also report strong crepuscular activity patterns associated with feeding. Oswald suggests that nighttime feeding by brown trout is also a common occurrence, so day/night offshore/inshore movements in Lake Ontario may be associated with feeding.

It was repeatedly noticed during brown trout radio-tracking operations that tracking success was often low during and after periods of heavy rainfall and increased shoreline wave activity that resulted in elevated nearshore turbidity levels. To follow up on these observations, daily fall 1980 and 1981 turbidity levels obtained from the Brockport Water Treatment Plant were plotted against percent tracking success (Figs. 12 and 13). Correlation analyses revealed a significant inverse relationship between tracking success (% of fish found on a given day) and nearshore turbidity levels ($p < 0.001$) explaining 45% of the variability in the fall 1980 data, although a comparison of the same relationship in fall 1981 did not prove significant ($p > 0.10$), probably due to a small sample size (3 fish). Calculation of tracking success was complex, as brown trout were not released into the lake at the same time and mortalities and stream entries reduced the sample size in the lake. The fall 1981 results were seriously affected by the inability to

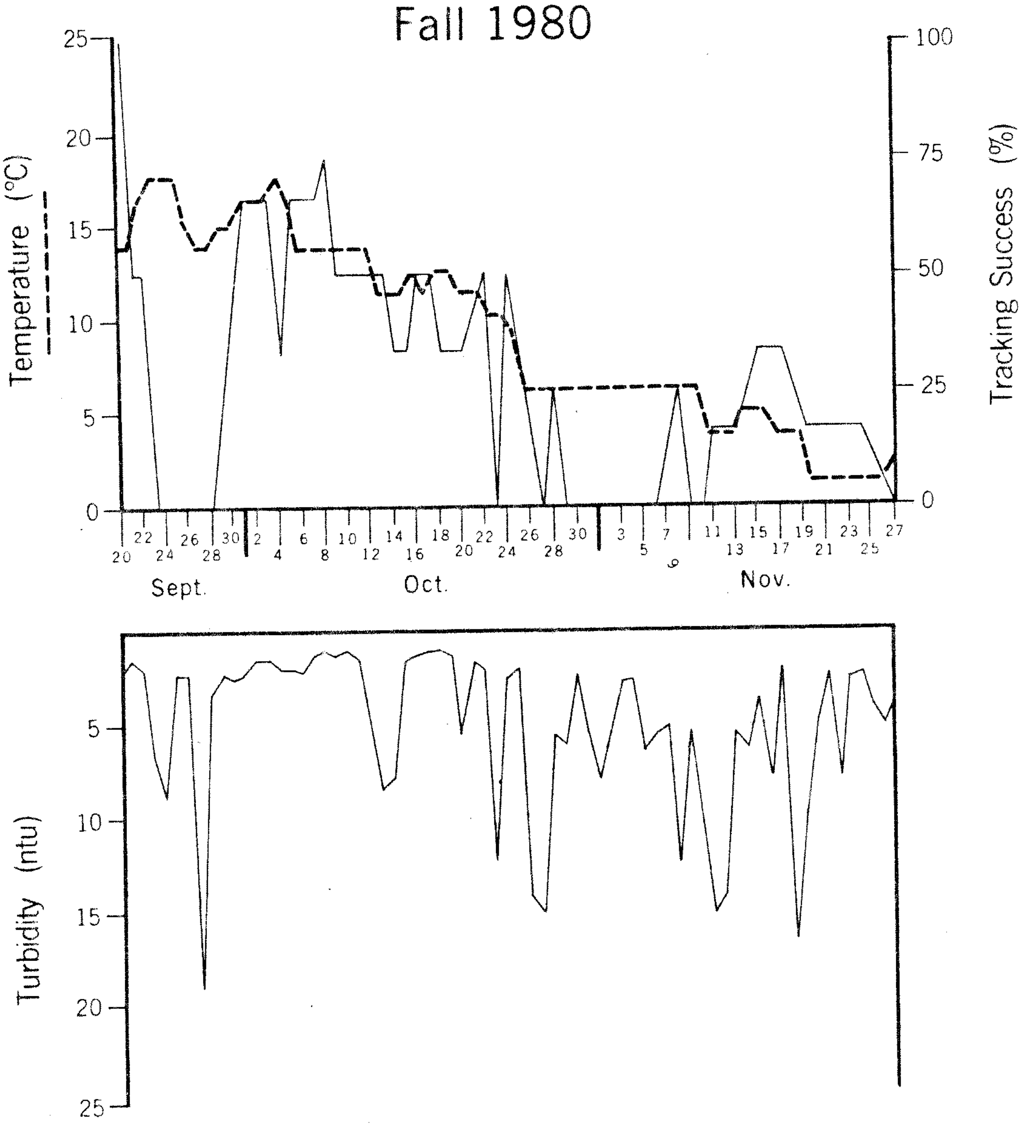


Fig. 12. Fall 1980 brown trout tracking success vs. nearshore water turbidity levels and temperature.

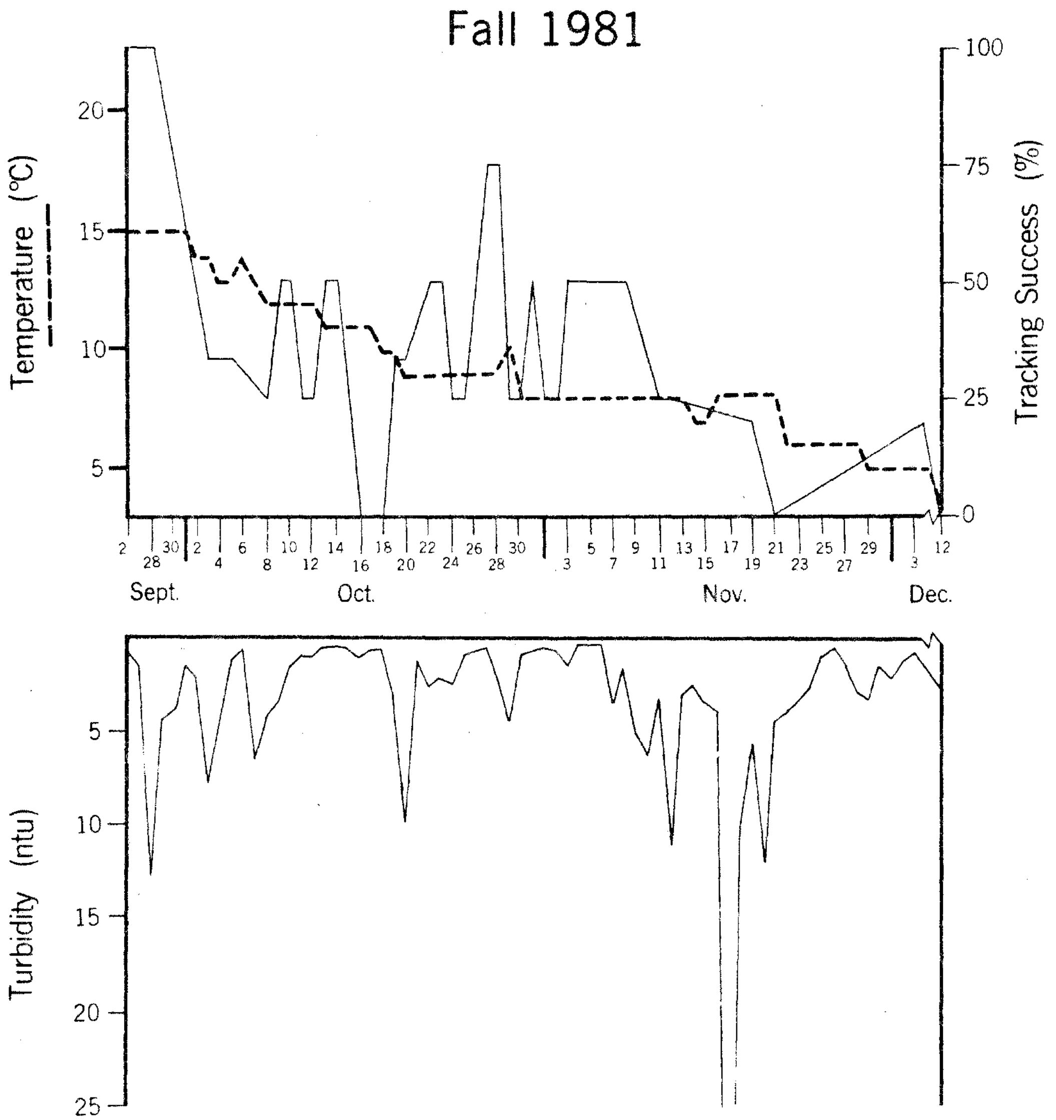


Fig. 13. Fall 1981 brown trout tracking success vs. nearshore water turbidity levels and temperature.

locate several fish that had moved beyond tracking range, leaving only 2 fish to contribute data over most of the sampling period though 5 were thought to be in the lake.

I suggest that nearshore turbidity tended to disperse brown trout to deeper offshore waters where particulates were much lower. The striking contrast between turbid nearshore waters and clearer offshore waters following such storm activity was readily apparent during boat and airplane tracking operations. Reasons for offshore movement in response to elevated nearshore turbidity could be gill abrasion, inhibited sensory perception, and inability to locate food if, in fact, forage fish do not react in the same manner to turbidity as brown trout.

Although nearshore turbidity may play a role in short-term inshore/offshore movement, it is water temperature that dictates seasonal periods of brown trout nearshore occupancy. To illustrate this relationship, temperatures from the Brockport Water Treatment Plant intake were plotted against fall tracking success (see Figs. 12 and 13). Note that in both fall 1981 and fall 1982, initial radio-tagged brown trout lake movements occurred at water temperatures of 18°C or less. Since brown trout were captured, radio-tagged, and released as early as they became available in and near Sandy Creek, it appears that when nearshore water temperatures approach 18°C, brown trout initiate inshore movement.

Note also that tracking success was reduced markedly as water temperatures fell below 8°C, though complete loss of contact with all fall radio-tagged brown trout did not occur until nearshore water temperatures fell below 4°C. Similarly, 52 temperatures transmitted from temperature sensitive fall 1980 transmitters ranged from 3.6 to 18.5°C. Interestingly, 77% of the transmitted temperatures ranged from 18-8°C.

Twenty-one percent (21%) of the transmitted temperatures were recorded in late fall for fish that could not select temperatures above 8°C due to the cooling of nearshore waters with the approach of winter. Thus only 2% of transmitted temperatures were out of the 8-18°C range when temperatures in that range were available near shore. Radio-tagged brown trout remained in warmer nearshore areas until nearshore water temperatures fell below 4°C, then they vacated nearshore areas and selected the deeper, warmer 4°C water where brown trout apparently over-winter. Three of 6 fall 1980 brown trout equipped with temperature sensing transmitters showed such offshore movements, moving beyond telemetry range in mid-November after transmitting ambient temperatures of 4.6 to 3.6°C. Therefore, it appears Lake Ontario brown trout prefer water temperatures in the 8-18°C range in fall, or waters as warm as possible below 8°C.

Wenger (1982) reports initial inshore movement of fall brown trout to occur in early September at nearshore temperatures of 20-21°C in Lake Erie, as determined by lakeshore beach seining. As early Lake Ontario electroshocking attempts in fall 1980,81 were largely confined to the lower reaches and mouth of Sandy Creek and initial brown trout captures occurred in mid-September, it is possible that sampling may have missed initial inshore brown trout movements in Lake Ontario prior to creek entry. Wenger does report, however, that Lake Erie brown trout inshore movements peak in early October at water temperatures of 16-18°C, values consistent with water temperatures and timing of peak inshore movement and creek entry of Lake Ontario brown trout.

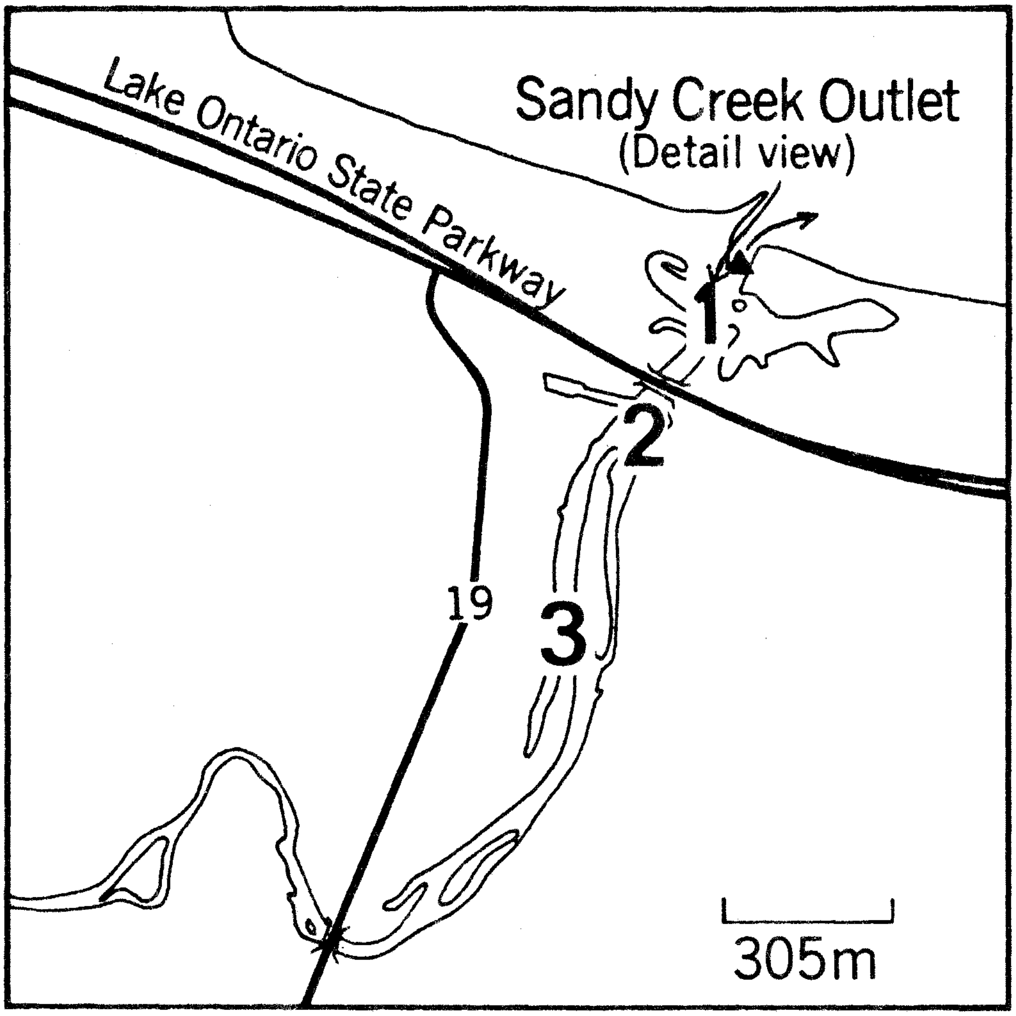
Fall radio-tagged brown trout mortality

During the fall 1980 radio telemetry study period, 2 brown trout mortalities were confirmed and both were related to sport fishing. Fish 210A was foul-hooked when a fisherman's line became entangled in the external transmitter while the fish was homing on its original stocking site at the Area 1 pier of Hamlin Beach State Park (see Fig. 8). The second fall 1980 fish probably died from wounds received after being caught twice by salmon snatchers after creek re-entry and subsequent entanglement in discarded monofilament fishing line under the Lake Ontario Parkway bridge crossing at Sandy Creek (Fig. 14). Reports of the capture of fish 110 reached researchers, and one of the fishermen was contacted. The fish, reported to be in "bad shape", was released after capture but died presumably from wounds, approximately 300m upstream from where it was caught. Fish 110 was assumed dead because it remained inactive until batteries failed, despite efforts to prompt movement or retrieve the transmitter. Both mortalities were related to transmitter snagging problems either directly (210A) or indirectly (110).

One other fall 1980 transmitter (340A) was found buried in a beach during the following fall 1981 tracking period. The last 1980 contact with fish 340A occurred at Devil's Nose on November 17 (Fig. 15). The transmitter was discovered 70km east of Sandy Creek near Hughes Marina during an airplane flight on October 10, 1981. Details of fish 340A's movements during the year between lost contact and rediscovery are unknown.

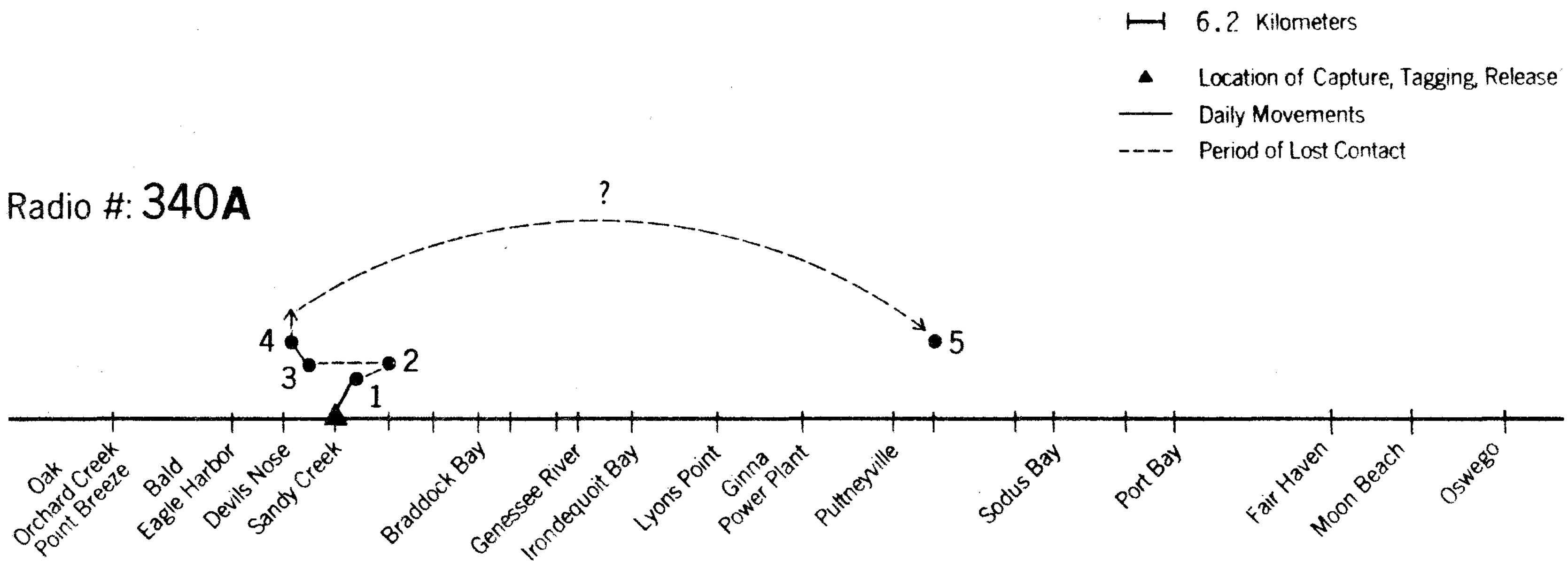
In fall 1981, one radio-tagged brown trout mortality was confirmed (fish 440) and another was suspected (fish 340B). In addition, 1 of the remaining 4 fall 1981 brown trout disappeared immediately after release.

Radio #: 110



Location:	Date:	
▲	9/20/80	
1	10/21/80	stream re-entry
2	10/22→29/80	- entangled in fishing line and released by snaggers
3	10/30→11/8/80	Dead

Fig. 14. Radio-tagged brown trout 110 fall creek movements.



Location	Dates	
▲	10/22/80	
1	10/22/80	
2	11/13/80	
3	11/15/80	
4	11/17/80	Moved offshore
5	10/10/81	Dead (transmitter found on beach during the following fall tracking season)

Fig. 15. Radio-tagged brown trout 340A lake movements.

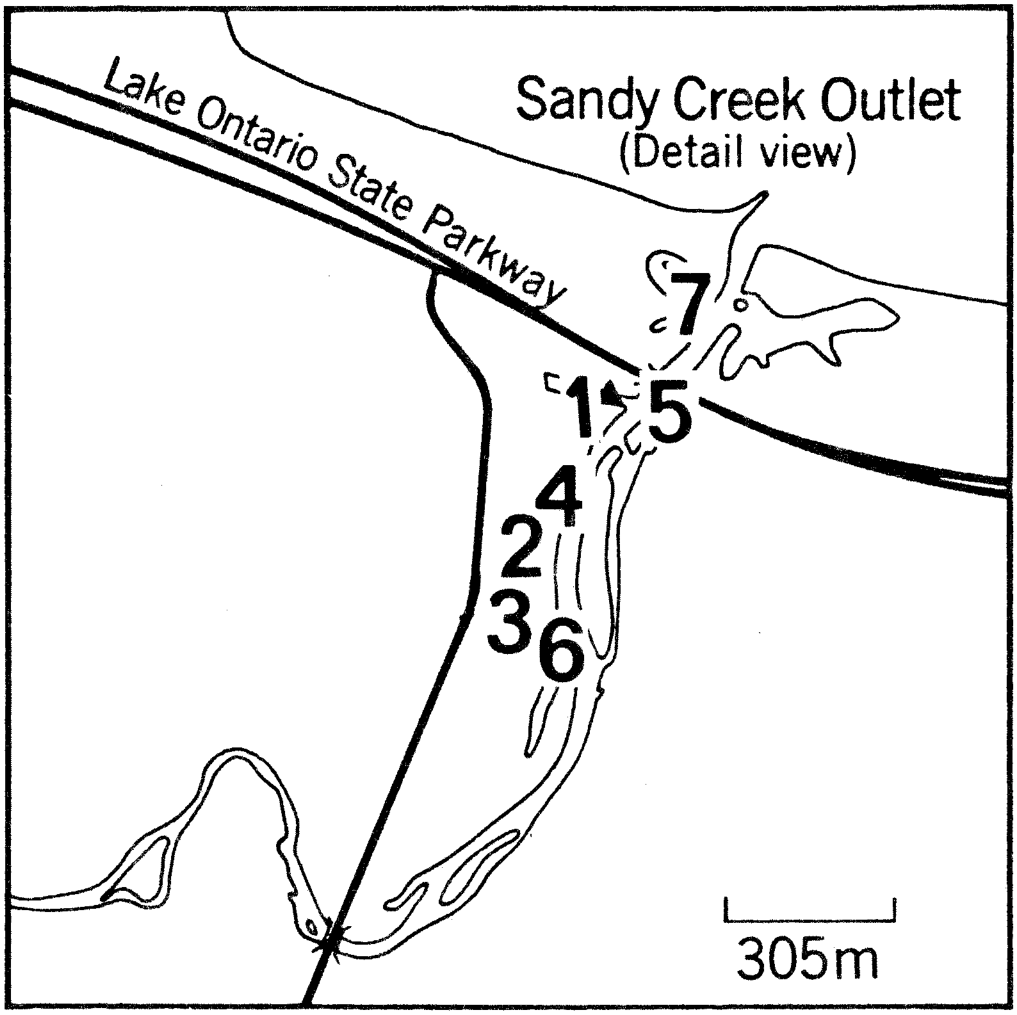
Surgically radio-tagged brown trout 440 was monitored only within the confines of Sandy Creek for an 18-day period before the fish became inactive in the Brockport Yacht Club basin (Fig. 16, point 7). Efforts to prompt movement or recover the transmitter were unsuccessful. This fish probably died as a result of complications following surgery. It had apparently fully recovered from surgery and was in excellent condition prior to surgical transmitter attachment. Fish 340B is a suspected mortality because it was found on only 5 occasions during a 49-day period and always near the point of release. This suggested possible transmitter malfunction causing an intermittent signal. This was never confirmed, however, and contact was eventually lost due to unobserved fish movement beyond telemetry range or total transmitter malfunction.

General movements and areas of preference of spring radio-tagged brown trout

Nearshore movements of spring surgically radio-tagged brown trout were recorded from April 16 to July 3, 1981, and individual brown trout movements are shown on track maps (Figs. 17,18,19,23,24; Appendix 2). Biological and stocking data are listed for individual spring radio-tagged brown trout in Table 3.

Typical of spring radio-tagged brown trout was initial eastward movement (20 of 22 fish) and an east/west reversal pattern of movement (15 of 22 fish) as illustrated by fish 690 (Fig. 17). This fish also ranged the farthest from the release site before moving offshore beyond tracking range in early July. There were, however, spring study fish that did not conform to typical movement patterns. Fish 660, though exhibiting initial eastward movement, was not observed to engage in east/west reversals (Fig. 18). Instead, 660 moved directly east to the Sodus

Radio #: 440



Location:	Date:			
▲	9/28 → 29/81	4	10/12/81	
1	9/30 → 10/5/81	5	10/13 → 10/14/81	
2	10/7 → 10/10/81	6	10/15/81	
3	10/11/81	7	10/16 → 12/12/81	(Dead)

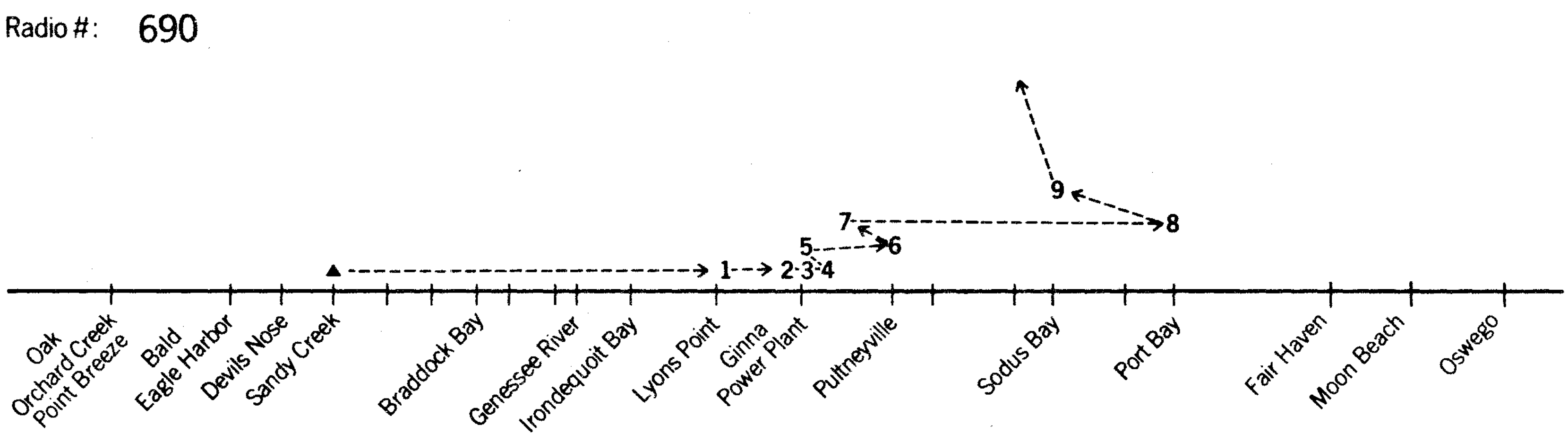
Fig. 16. Radio-tagged brown trout 440 fall creek movements.

Table 3. Biological and stocking site information for spring radio-tagged brown trout.

Spring 1981

Radio tag frequency	Length (cm)	Weight (kg)	Sex	Hatchery clips	Age[1]	Stocking site
510	48.3	1.9	Male?	LV-AD	II	Rochester-Hamlin
740	49.2	2.5	Male?	AD	II	Rochester-Hamlin
660	53.0	3.0	Male	AD	II	Rochester-Hamlin
630	45.6	1.8	Male?	-	II	?
540A	56.9	3.2	Male	-	III	?
550	46.0	1.8	Male	-	II	?
710	43.8	1.4	Male?	-	II	?
650	46.7	1.7	Male?	-	II	?
560	45.6	1.7	Male?	-	II	?
730	49.5	1.9	Male	AD	II	Rochester-Hamlin
570	49.5	2.0	Male?	-	II	?
580	49.0	2.1	Male?	-	II	?
610	44.2	1.5	Female?	-	II	?
690	48.8	2.0	Female?	-	II	?
720	45.4	1.7	Male?	-	II	?
620	44.8	1.5	Male?	RP	II	?
770	44.4	1.5	?	AD	II	Rochester-Hamlin
700	49.5	2.8	Male	-	II	?
670B	48.6	1.5	Male	LP	II	?
540B	45.6	1.5	Female?	-	II	?
640	51.4	2.3	Male	-	II	?
600	50.3	2.1	Female?	-	II	?

[1]Age was determined from length/weight comparisons with Lake Ontario brown trout data from Eckert (1983).



Location	Dates
▲	4/21/81
1	4/30/81
2	5/04/81 ⟶ 5/14/81
3	5/20/81 ⟶ 5/22/81
4	5/25/81
5	5/29/81
6	6/01/81 ⟶ 6/12/81
7	6/15/81
8	6/21/81
9	7/03/81

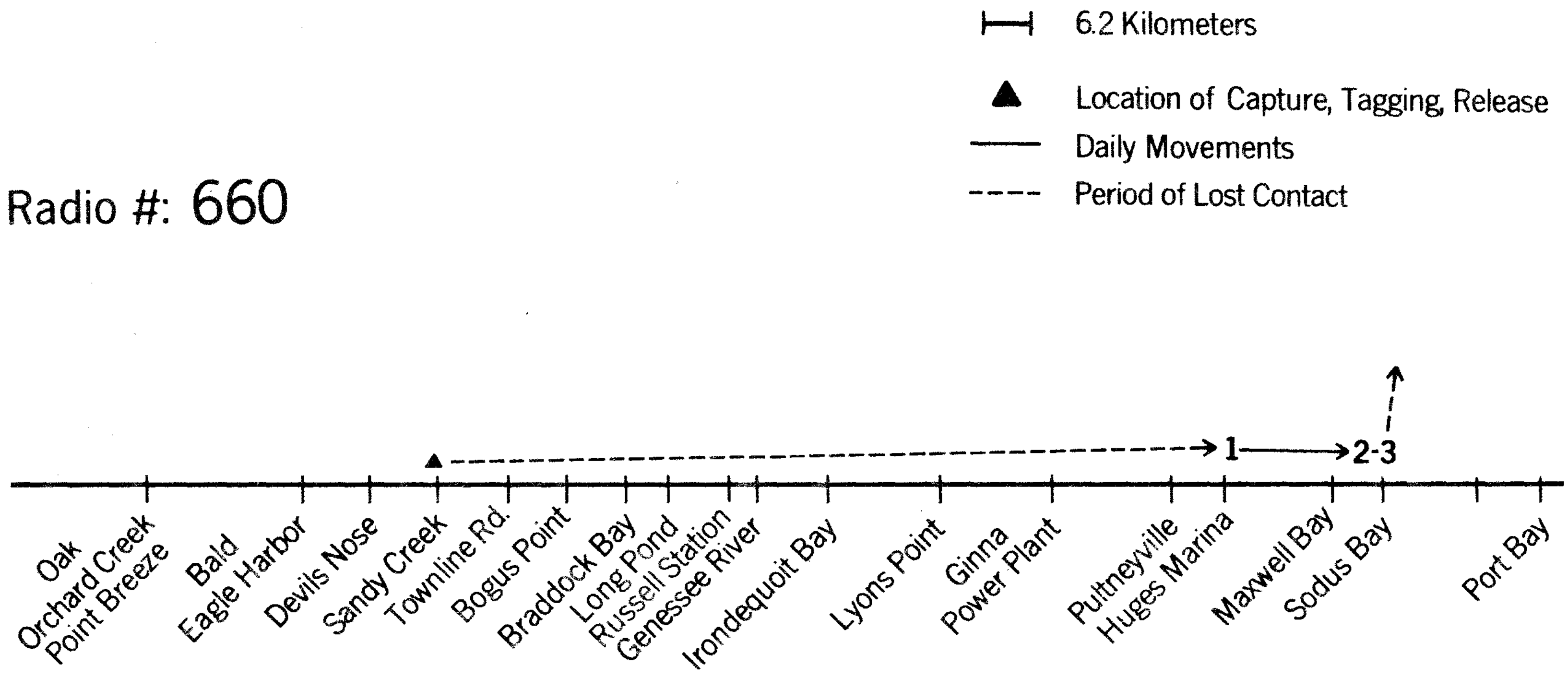
├─┤ 6.2 Kilometers

▲ Location of Capture, Tagging, Release

——— Daily Movements

- - - - Period of Lost Contact

Fig. 17. Radio-tagged brown trout 690 spring lake movements.



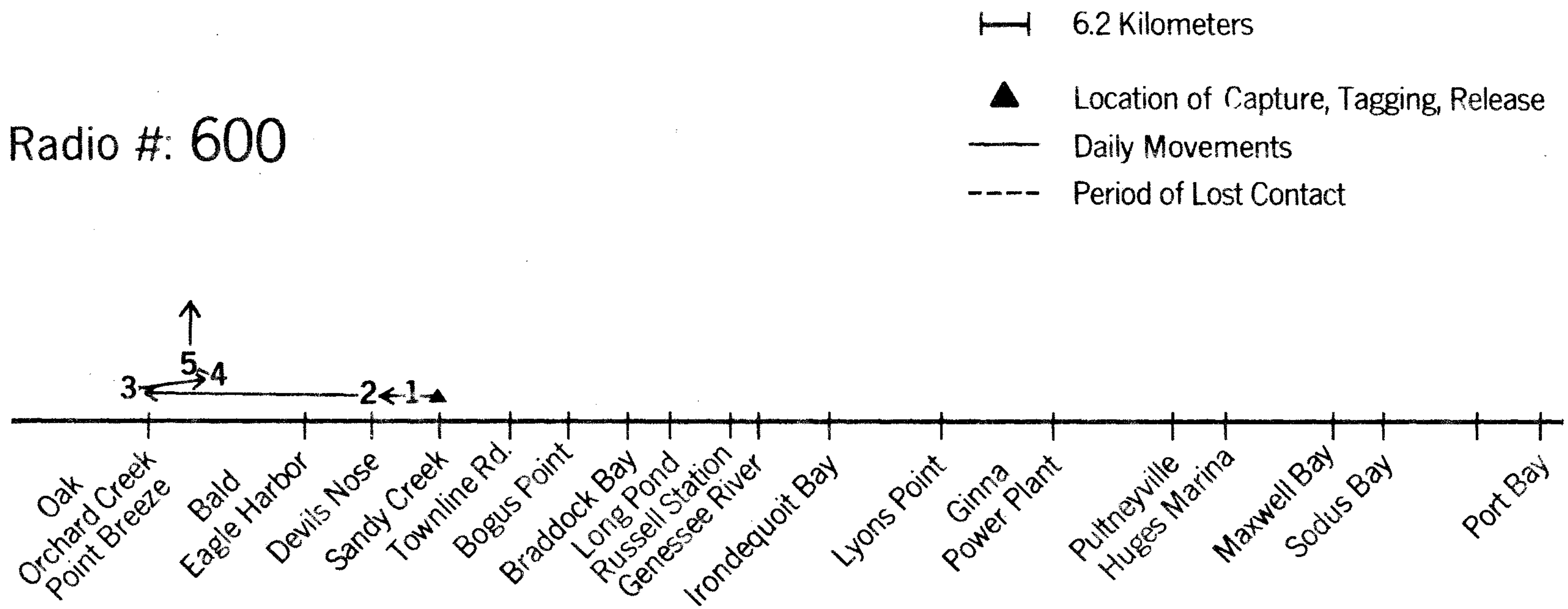
Location	Dates
▲	4/16/81 ⟶ 4/17/81
1	4/26/81
2	4/30/81
3	5/02/81 ⟶ 7/03/81

Fig. 18. Radio-tagged brown trout 660 spring lake movements.

Bay breakwall where it remained for 2 months before moving offshore after July 3. Initial westward movement also occurred (2 of 22 fish), as exhibited by fish 600, which was tracked for an 8-day period before moving beyond tracking range in mid-May (Fig. 19).

Unlike fall brown trout, spring brown trout did not confine their movements to localized areas (Hamlin Beach to the Genesee River) nor did they exhibit distinct perferences for original stocking locations. However, preference was shown for certain nearshore areas (see Fig. 20). Spring brown trout seemed particularly interested in stream and power plant outflows, often interrupting movements to remain in those areas for extended periods. Two very definite areas of preference were exhibited: Sandy Creek, which was to be expected because brown trout were captured and released there (although 7 fish returned to the Sandy Creek area after initial movements away from the creek); and Lyon's Point and adjacent areas, which are 22 to 62km east of Sandy Creek, and where outflows are more numerous (12) in comparison to the number of outflows (7) in the 40-km area centering on Sandy Creek. Fish 690 exhibited a preference for the Ginna Power Sation outflow (see Fig. 17). In spring, natural outflows are typically warmer than lake waters, as are power plant outflows. Streams and power plant outflows were observed to attract brown trout as well as large numbers of smelt and alewives in spring. Similar forage fish (Spigarelli _et al_. 1982) and salmonid (Spigarelli and Thommes 1976, 1979) attraction to thermal plumes was reported in Lake Michigan. Spigarelli and Thommes suggested that the combination of an abundant food supply and responses to preferred temperatures may cause salmonid attraction to thermal plumes.

Spring radio-tagged brown trout engaged in wider ranging movements



Location	Dates
▲	5/05/81
1	5/05/81
2	5/06/81
3	5/08/81
4	5/10/81
5	5/13/81

Fig. 19. Radio-tagged brown trout 600 spring lake movements.

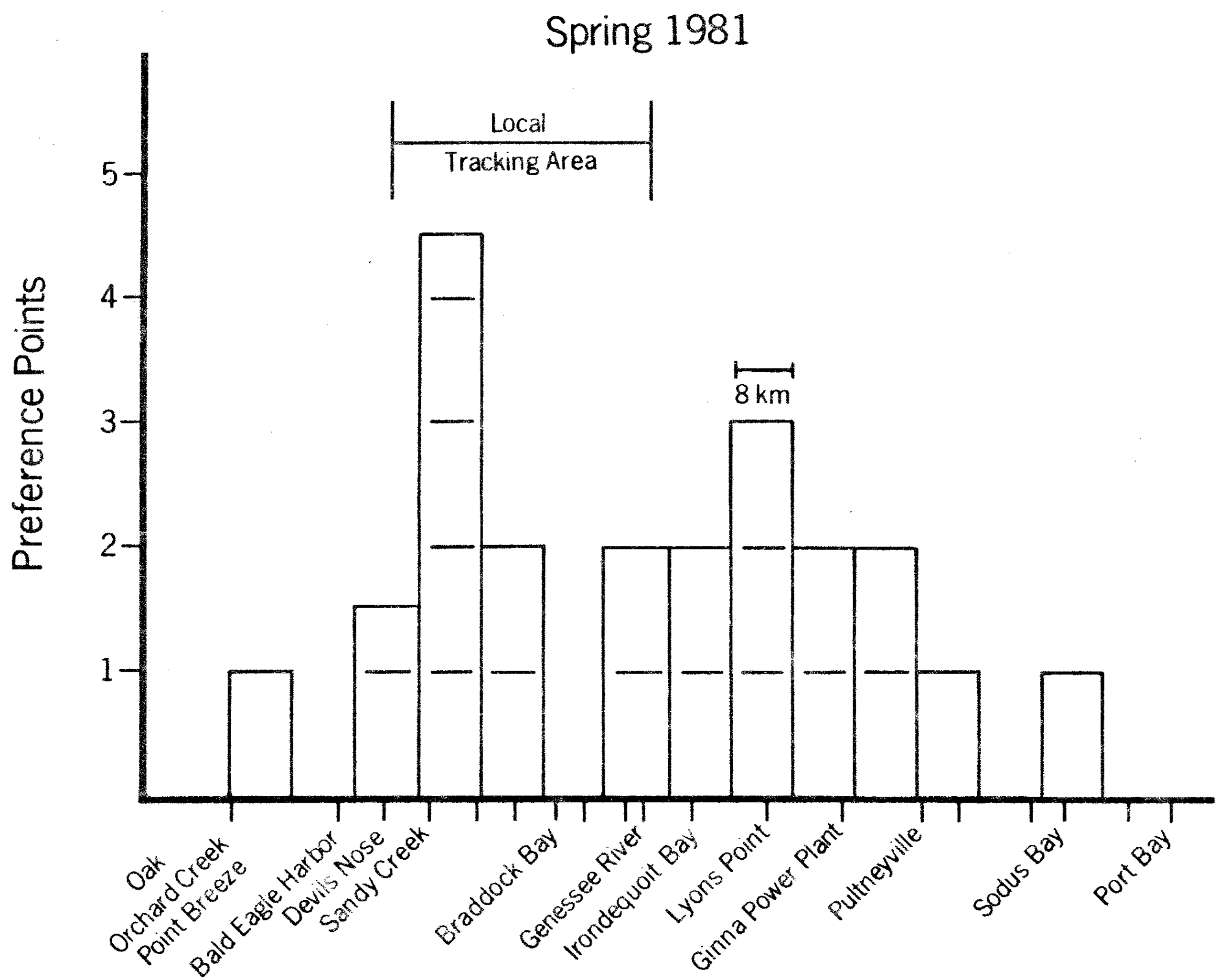


Fig. 20. Spring preferred areas. Preference points were assigned to 8km areas where tagged fish were found during three or more successive tracking operations.

than fall fish and in a predominantly eastward direction (see Fig. 21). The profound lack of westward movement is subject to considerable speculation and probably results from 2 factors: 1) the current in this region of Lake Ontario is predominantly eastward; and 2) surgical transmitter attachment subjected fish to greater stress, which may have been reflected by longer periods of inactivity immediately following release when compared to externally radio-tagged fish. Therefore, surgically tagged brown trout may have drifted with the current until fully recovered, when typical east/west movements took place.

The possibility of eastward movement being temperature related was ruled out by comparing daily water temperatures from the Ginna and Russel Power Stations with those of the Brockport Water Treatment Plant. A series of t-tests revealed no significant differences in water temperature between these locations ($p \leq 0.54$) over the spring tracking season.

Spring radio-tagged brown trout daily movements

Because of a lack of external sexual characteristics in spring brown trout, determination of sex was not reliable. Guesses were made, however, and are listed with hourly movement rates of individual fish determined from successive daily tracking operations (Table 4). Notice that regardless of sex, individual daily movement rates reveal a much wider range among individual spring brown trout than for fall radio-tagged fish (see Table 2). Because of sexing difficulties and the fact that only 2 females were identified (questionably), a comparison of movement rates by sex could not be applied to the spring and fall study groups. There was, however, the opportunity to combine sexes and to

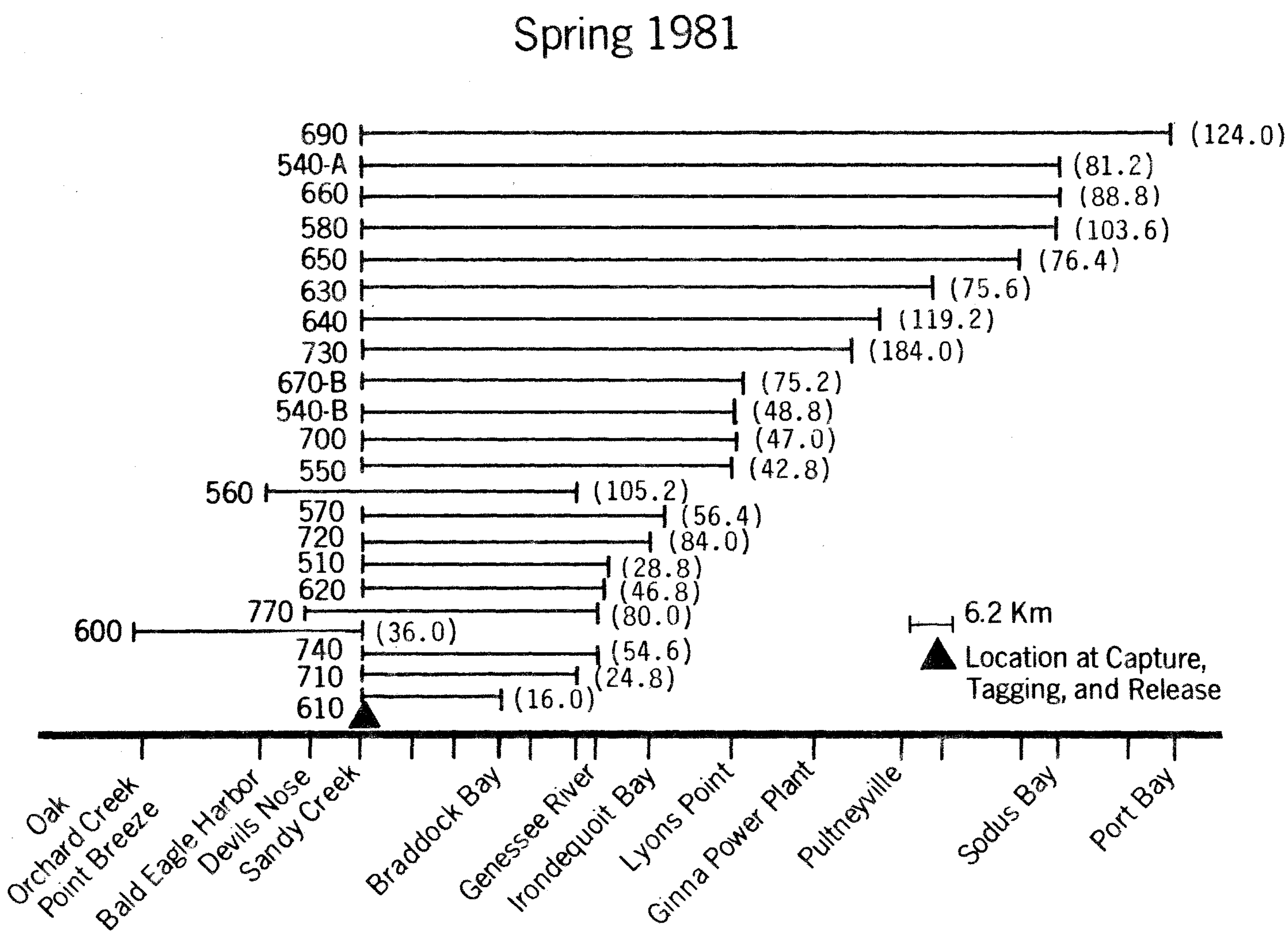


Fig. 21. Range of movements (total km moved) of Lake Ontario brown trout with surgically attached radio transmitters in spring 1981.

Table 4. Spring radio-tagged brown trout day-to-day distances traveled converted to kmh^{-1}.

Spring 1981

Sex	Transmitter frequency	Movement rate (kmh^{-1})
Male?	560	.91, .13, .30
Male?	720	.26
Male?	630	.33
Male?	740	.32, .61, .25
Male?	620	.51, .05, .35, .65
Male	730	.29, .78, .34, .18, .23, .35
Male?	640	.38, .21, 1.10, .94, .52, .57, .46
Male	670B	.43, .05, .12, 1.19
Male	700	.56
?	770	.05, .30, .21, .81
Female?	540B	.07
Female?	600	.25

[1]Sexing was unreliable due to the lack of external sexual characteristics in spring.

statistically compare movement rates (kmh^{-1}) of spring radio-tagged brown trout with fall radio-tagged brown trout, but a t-test revealed no significant differences ($p=0.23$). Combined with the widely ranging movement rates observed for individual spring brown trout regardless of sex, this suggests that movement rates of male and female brown trout probably do not differ significantly in the spring. A t-test of the difference in mean variability within spring and fall fish was significant ($p=.003$). Movement rates appear to differ between sexes only during fall when movements are more closely associated with reproductive maturity. The maximum movement rate for a spring surgically tagged fish was $1.19kmh^{-1}$ ($28.6kmday^{-1}$).

Factors influencing spring inshore/offshore movement

As in fall 1980, elevated nearshore turbidity levels seemed to reduce brown trout tracking success in spring 1981. Note the major reduction of tracking success during mid-April when nearshore turbidity was at a springtime peak (Fig. 22). Seven fish were in the lake at that time and all apparently moved offshore beyond tracking range, presumably in response to high turbidity. Correlation analysis again revealed a significant inverse relationship between tracking success and nearshore turbidity levels ($p<0.005$). Although the sample size was considerably larger than during fall study periods (as many as 15 active fish in the lake), spring turbidity levels were generally too low to suggest a cause-and-effect relationship between nearshore turbidity and tracking success. Despite nature's non-cooperation in this respect, it appears that elevated nearshore turbidity does play a role in prompting periods of offshore movement especially in view of the

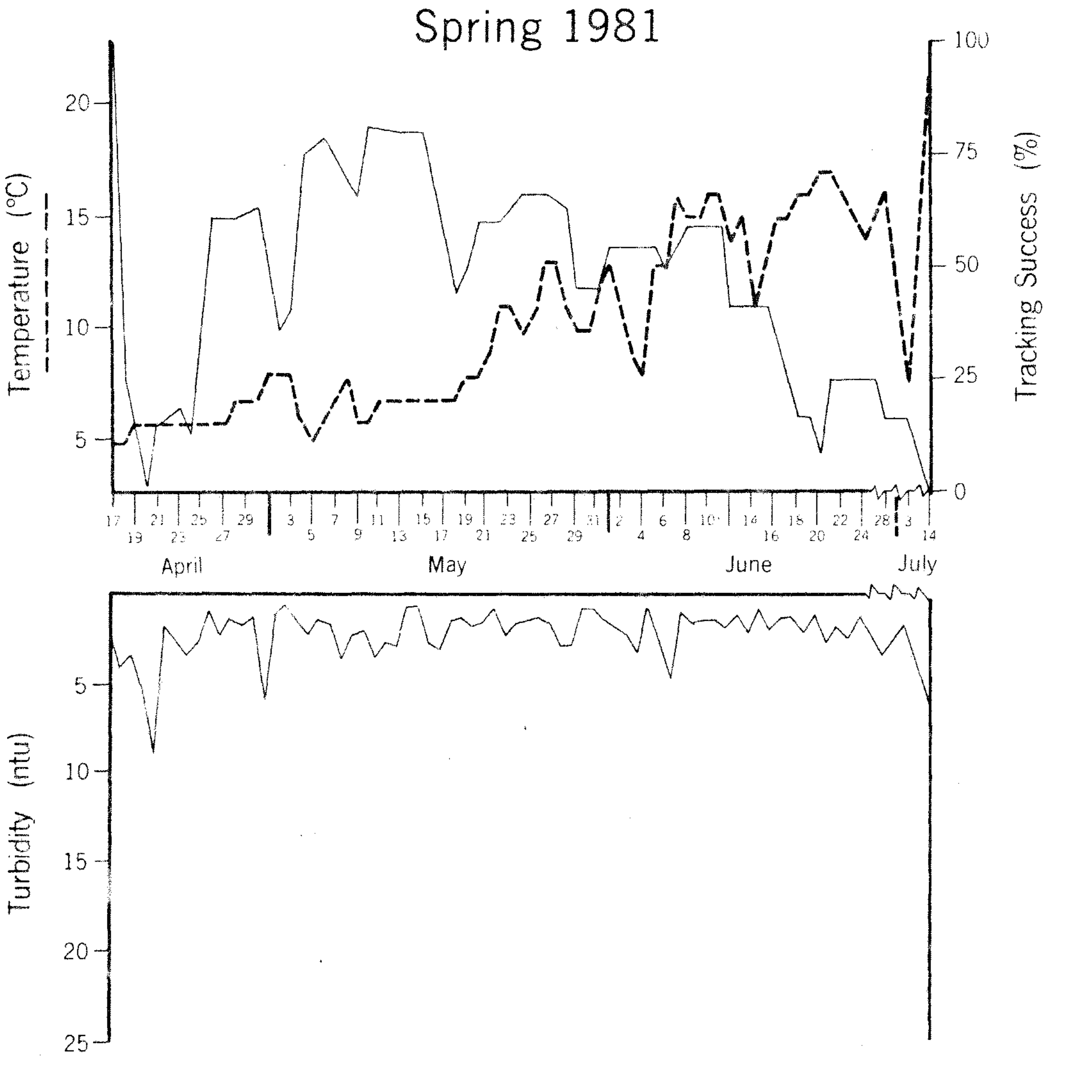


Fig. 22. Spring 1981 brown trout tracking success vs. nearshore water turbidity levels and temperature.

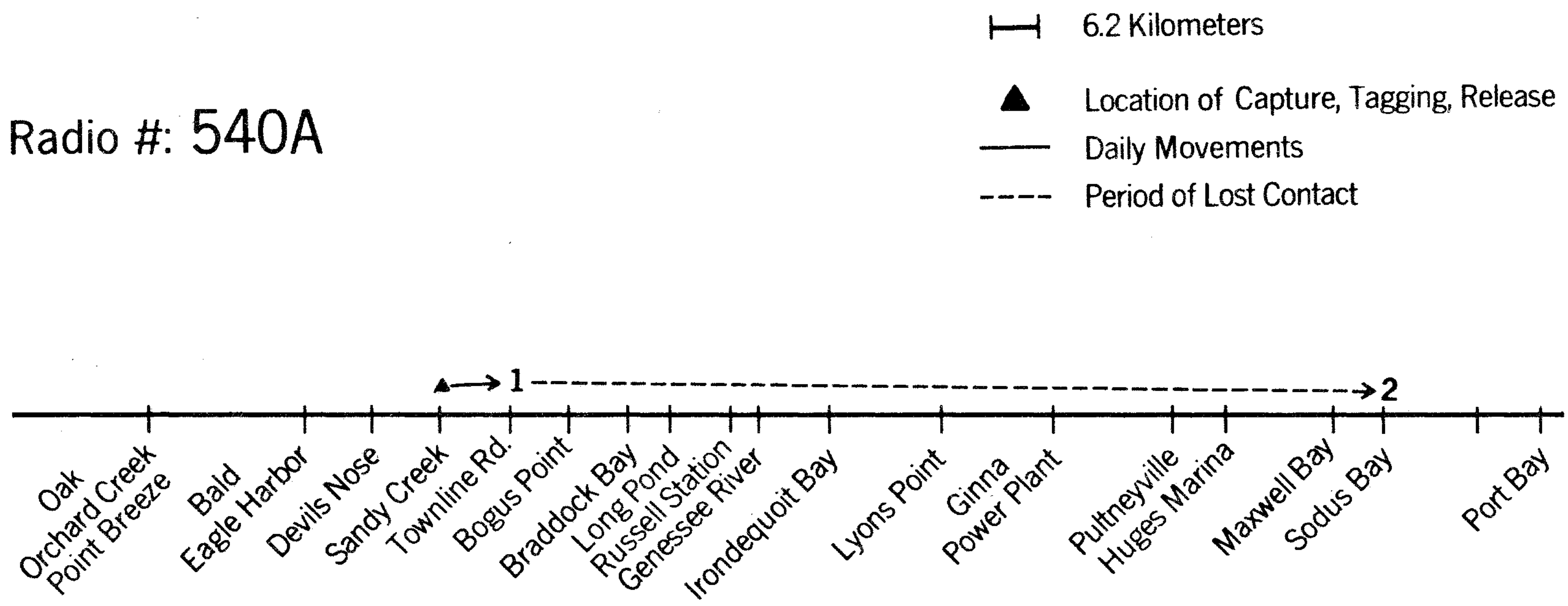
the relationship observed in fall 1980.

Periods of spring radio-tagged brown trout movements were very similar to periods of fall radio-tagged brown trout movements in relation to temperature. The major difference was that the initiation and termination of nearshore movements were associated with spring warming as opposed to fall cooling of Lake Ontario waters. Daily water temperatures were plotted with spring 1981 radio-tagged brown trout tracking success (see Fig. 22). Initial brown trout inshore movement occurred at nearshore temperatures of 5°C as determined by the earliest spring brown trout captures in Sandy Creek and adjacent shallow Lake Ontario waters. Inshore brown trout movement appears to occur as soon as nearshore waters warm above 4°C. Offshore movement to deeper waters occurred as nearshore water temperatures approached and exceeded 18°C (see. Fig. 22). Although brown trout tracking success appears to peak at nearshore water temperatures less than 8°C, brown trout transmitter-related temperatures indicate that an 8-18°C range was preferred. A total of 186 individual transmitted daily ambient water temperatures ranging from 4.6-19.9°C were recorded for active spring brown trout in Lake Ontario. Of that total, 83% were in the 8-18°C range. Of the remainder, 10% were recorded before lake waters had warmed to 8°C. By eliminating the transmitter-related temperatures recorded when warmer 8°C water was not yet available, 93% of the spring brown trout ambient temperatures were within the 8-18°C range, although cooler water was easily obtainable by moving deeper or further offshore. On only 4 occasions did brown trout occupy water with temperatures above 18°C during spring nearshore movements, indicating that they avoid waters above 18°C in preference for deeper, cooler, offshore waters where they spend the summer (see summer results and discussion).

Spring radio-tagged brown trout mortality

Mortality of spring radio-tagged brown trout was attributed to sport fishing and surgical attachment of transmitters. At least 1 and probably 2 surgically tagged brown trout were legally caught by anglers during the spring study period, an indication of active feeding and good health. The confirmed catch occurred at Sodus Bay, 14 days after fish 540A re-entered the lake from the capture/release site at Sandy Creek (Fig. 23). This fish traveled at least 80.2km during that period and was reported to have fought well and to be in good health at the time of capture. In short, when brown trout recover from the stress of surgical attachment, they perform normally.

Unfortunately, this was not the case for many surgically tagged brown trout in spring 1981. A distressingly high 36% (8 of 22 fish) mortality rate occurred for spring brown trout, presumably due to after-effects of surgical transmitter attachment. I attribute the mortality to post-surgical attachment effects because all mortalities occurred within 4 weeks of release, and all fish appeared healthy and were behaving normally upon release. Though anesthesia may have contributed to 2 deaths occurring during the surgical procedure, all released fish had apparently recovered from anesthesia as indicated by active swimming before and after release. Field mortality was assumed upon termination of all movement activity and/or long-term presence of brown trout in unsuitable habitat. Recovery of 3 transmitters, one with the carcass and 2 after decomposition had separated the transmitter from the fish, confirmed mortalities. All three recovered transmitters were found buried in muddy or sandy sediments. Five other suspected mortalities were confirmed by failure of field crews to prompt movements, despite



Location	Dates
▲	4/16/81 ⟶ 4/20/81
1	4/02/81
2	5/04/81
	Caught in Fishing Derby

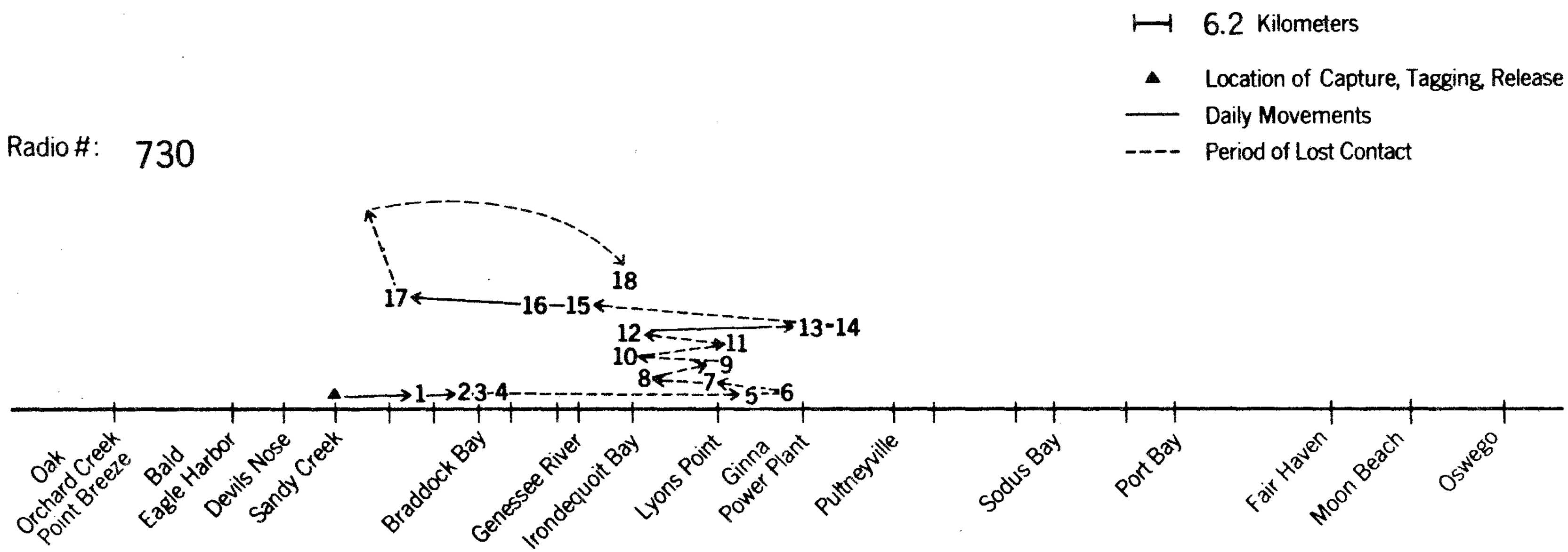
Fig. 23. Radio-tagged brown trout 540A spring lake movements.

active attempts to recover transmitters. These non-moving transmitters remained in 20°C+ shallows during the summer until batteries failed. Fish movements before death are shown in Appendix 2.

Although mortality was high, the majority of spring surgically tagged brown trout did survive and, I believe, exhibited natural movements. One fish (730) provided a bonus by returning to its apparent preference area during the following fall 1981 tracking season (Fig. 24). It apparently died at that location, but it had survived a period of 6 months with no apparent ill affect from the surgically attached transmitter as was exhibited by its widely ranging spring movements and survival through summer. This fish exhibited the longest movement of spring radio-tagged brown trout (184km).

Transmitter attachment method applications

Transmitter attachment methods require considerable contemplation prior to employment in field studies. Though external attachment has its benefits, it also subjects fish to considerable water resistance and entanglement potential (Mellas 1982). Although water resistance did not seem to cause any problems in the lentic environment of Lake Ontario, 2 externally radio-tagged brown trout were caught by fishermen after becoming entangled in fishing line. Weed entanglement must also be a concern during bay and stream movements though no such problems were evident during my study. Surgical transmitter attachments have no external components. For this reason, surgical transmitters can be expected to remain with fish for longer periods if incisions heal properly. The major problem with surgical attachment is in the relatively difficult surgical procedure, where lengthy attachments under



Location	Dates		Location	Dates	
▲	4/21/81		12	6/10/81 ⟶	6/15/81
1	4/23/81 ⟶	4/25/81	13	6/18/81	
2	4/26/81		14	6/19/81	
3	4/28/81		15	6/22/81	
4	4/30/81		16	6/23/81	
5	5/04/81		17	6/25/81	
6	5/06/81 ⟶	5/10/81	18	9/20/81	11/30/81
7	5/13/81 ⟶	5/22/81			
8	5/25/81				
9	6/01/81 ⟶	6/06/81			
10	6/08/81				
11	6/09/81				

Fig. 24. Radio-tagged brown trout 730 spring lake movements.

adverse weather and sanitary conditions in the field subject both the fish and surgeon to considerable stress. Laboratory experiments by McCormack (1980) suggest that surgical attachment is the better of the two attachment methods though Mellas (1982) recommends stomach insertion, a technique considered but not utilized due to known regurgitation problems in salmonids (McCleave et al. 1978; Mellas 1982).

Based upon my experiences, several techniques could be employed to improve both attachment methods. The snagging potential of external transmitters could be reduced by tapering the forward portion of transmitters toward the fish body and looping the forward attachment wire over the tapered area before inserting the wire through the dorsal musculature. In this manner, potential snags would more easily pass over the transmitter without harm. Reduction of water resistance through streamlining would also occur. Further research leading to better surgical attachment methods and smaller transmitter components, particularly battery size, could improve survival of surgically tagged fish. Research in anesthetic type and dosage in varying water temperatures would also be helpful for both attachment procedures. Sylvester and Holland (1982) have presented data concerning anesthetic application in varying water hardness, temperature, and pH that could prove helpful in the future.

Applications to the spring and fall brown trout fishery

Time periods of Lake Ontario brown trout nearshore occupancy were mid-September to early December and mid-April to early July. Longer than expected nearshore occupancy by brown trout in late spring and early summer 1981 suggests that shoreline and nearshore brown trout angling could be extended later in the spring than was observed by field crews. Apparently, nearshore anglers either tire of fishing by mid-June or are ignorant of the fishing potential that is provided by late spring and early summer brown trout presence in nearshore waters. Another deterrent to nearshore angling during this time period may be the prevalence of downrigger-equipped fishermen who actively seek out the more prized Pacific salmon, lake trout, and rainbow/steelhead trout which are typically found deeper and/or further offshore. A defeatist attitude may arise in nearshore anglers when sighting "geared to the teeth" anglers moving further toward the horizon in their well-equipped craft.

Although potential for fall Lake Ontario brown trout angling success is high, many fishermen appear to select against brown trout in preference for the typically larger Pacific salmon which are also abundant in fall nearshore waters. The concentration of fishing effort directed toward Pacific salmon is demonstrated by the proliferation of salmon snatching in designated tributaries during the fall season. The presence of brown trout in nearshore waters in late fall is also neglected by most anglers who either tire of fishing or are deterred by cold weather. Late fall, winter, and early spring brown trout angling at heated effluents offers additional opportunity to those fishermen who have the "stuff" to brave the cold weather. Brown trout harvests could be markedly increased if angling effort were increased during these presently under-utilized periods.

A strong homing drive in Lake Ontario brown trout in fall and their apparent preference for outflow areas in spring and fall offer the nearshore angler, who concentrates fishing activities in such areas, ample opportunity for angling success. In short, fishermen should concentrate nearshore angling efforts at preferred brown trout nearshore areas when water temperatures are 8-18^{o}C and when nearshore water turbidity is low.

Management concerns

The practice of blind snatching in Lake Ontario tributaries during concurrent fall Pacific salmon and brown trout spawning runs results in many incidental catches of brown trout. Though I suspect that most snatchers abide by the law and release trout, several snatchers were observed to keep them. Although a sound management practice in its intent to harvest salmon which die after the spawning run, I suspect that brown trout suffer considerable mortality from wounds and illegal catches. Research to determine the rate of incidental non-target species mortality induced through the practice of blind snatching would be helpful to more fully evaluate snatching's effect on the brown trout fishery.

Summer Lake Ontario brown trout habitat

During summer, systematic vertical gill netting permitted the determination of brown trout depth distribution within the Lake Ontario water column. Netting over standard depths at varying distances from shore (see MATERIALS AND METHODS) indicated that brown trout limit their summer habitat utilization to relatively nearshore waters where the total depth is less than 50m (Figs. 25 and 26). A total of 20,720m^2 of vertical gill net was set and retrieved in good order during the combined 1981-82 summer sampling periods. Only 3 brown trout (6.3 CPUE) were caught at the 47-m standard depth while catches were considerably higher at 32-m (31 fish, 31 CPUE) and 17-m (42 fish, 73.8 CPUE) standard depths (Table 5). Roughly half the effort was expended at these shallower

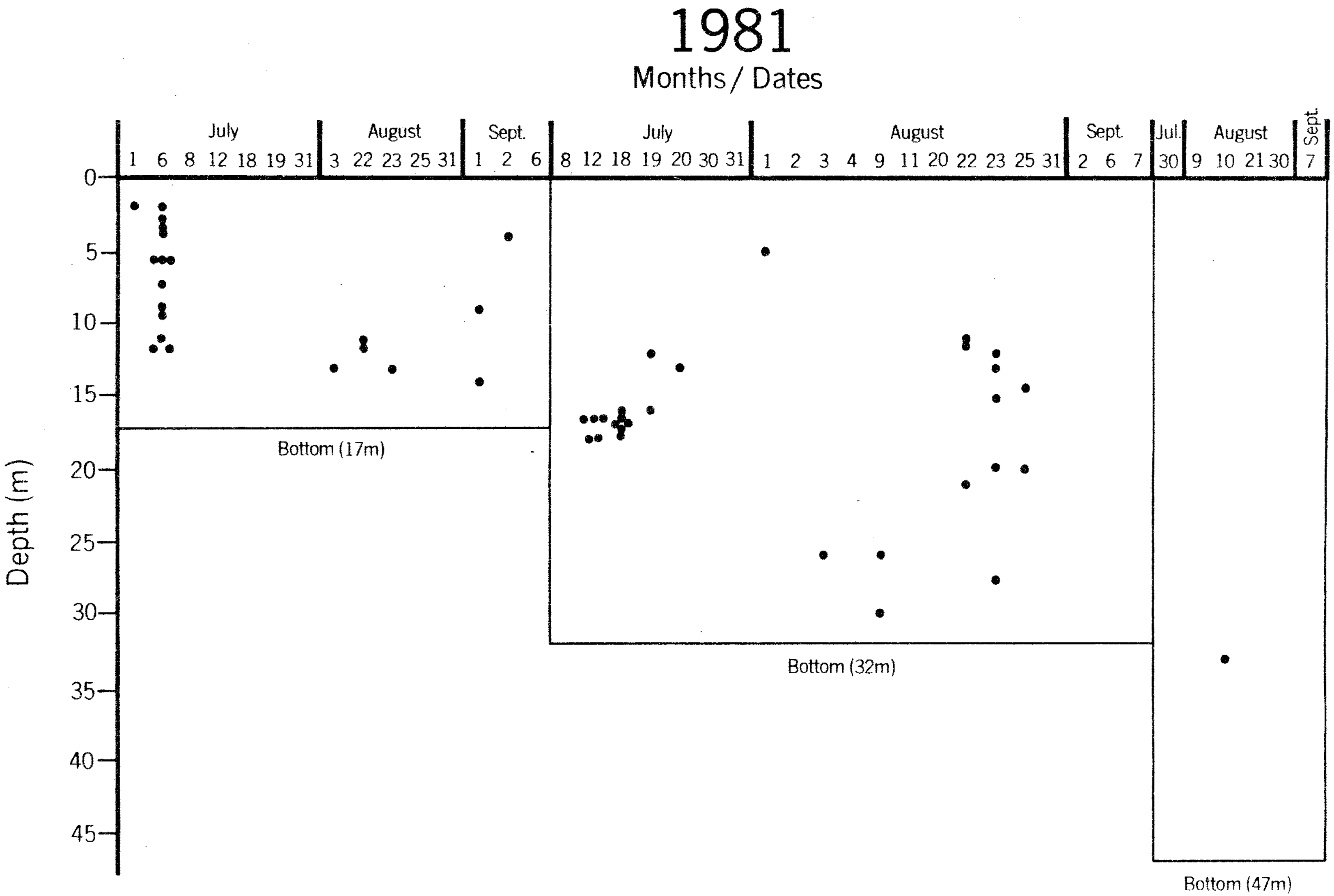


Fig. 25. Depth, date, and standard netting depth of brown trout capture (1981).

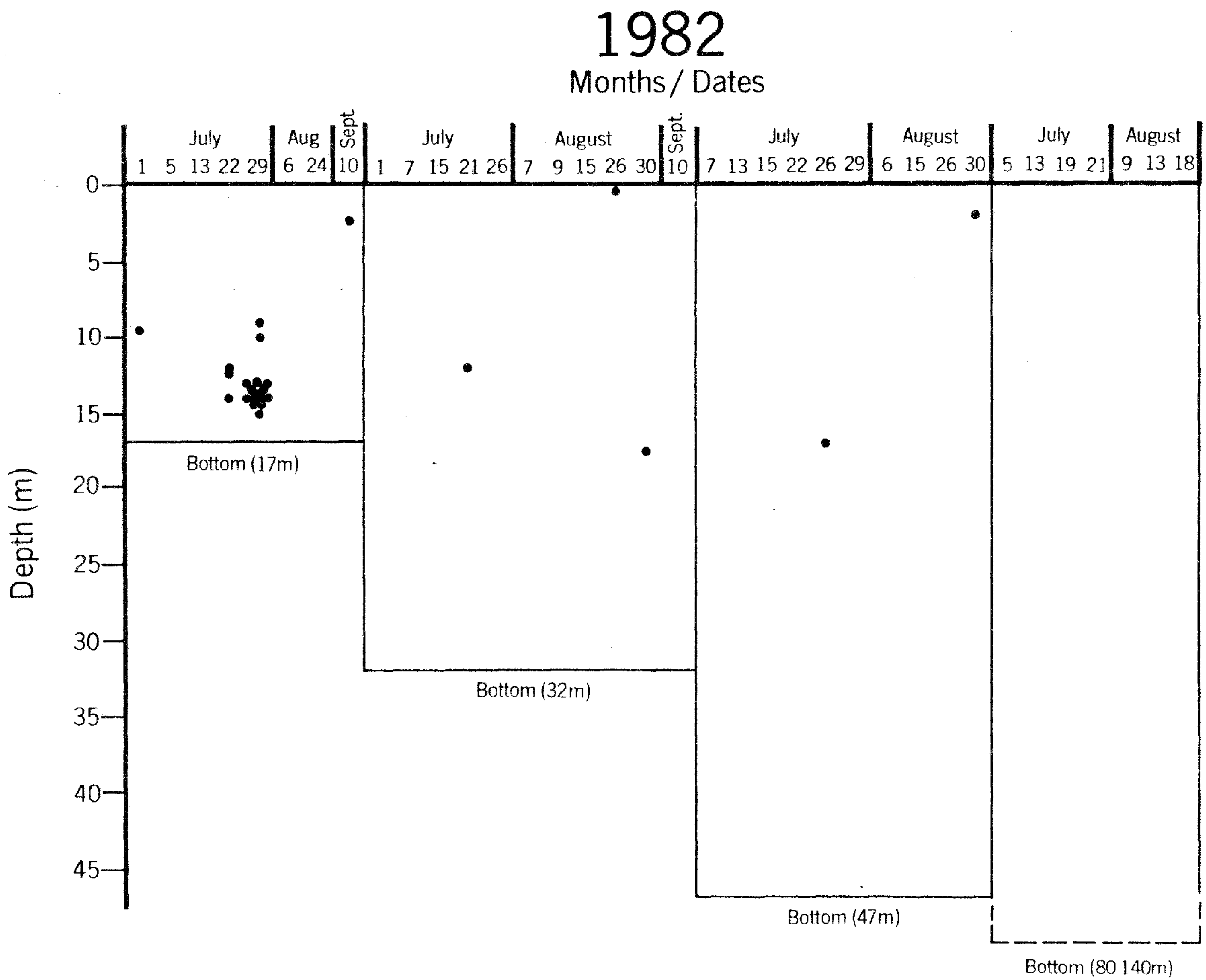


Fig. 26. Depth, date, and standard netting depth of brown trout capture (1982).

Table 5. CPUE conversions for 1981 and 1982 summer vertical net brown trout catches.

Standard Netting Depth	m^2 of Vertical Net [1]	Number of Brown Trout Caught	CPUE Conversion Factor	CPUE
1981				
17m	3695	21	1.8	37.8
32m	6610	28	1.0	28.0
47m	1885	1	3.5	3.5
> 47m	0	-	-	-
total	12190	50		
1982				
17m	1450	20	1.9	38.0
32m	2720	3	1.0	3.0
47m	2620	2	1.0	2.0
> 47m	1740	0	1.6	0.0
total	8530	25		
1981 & 1982 combined				
17m	5145	41	1.8	73.8
32m	9330	31	1.0	31.0
47m	4505	3	2.1	6.3
> 47m	1740	0	5.4	0.0
total	20720	75		

[1] Represents only the net set in water warmer than 4°C.

depths ($\leq$ 47m) in 1982 as opposed to 1981, and that difference is reflected in the respective sample sizes. No brown trout were caught over depths greater than 47m (approximately 4km from shore) despite 1982 netting efforts over much deeper waters.

The apparent presence of brown trout only in relatively shallow nearshore areas of Lake Ontario suggests that brown trout may indeed have an affinity for the lake bottom as reported by Abraham (1979) (using bottom set horizontal gill nets), but that relationship appears less distinct than Abraham reported. There does, however, appear to be a brown trout association with the intersection of the thermoclinal zone and bottom as exhibited by the high brown trout catch in the 17-m standard set of July 29, 1982 (see Fig. 26), when nets were set in and near that intersection. The close proximity of the thermoclinal zone to the bottom in waters less than 32m deep may hold summer brown trout relatively nearshore in Lake Ontario.

Water temperatures were assigned to brown trout based upon the depth of capture and are displayed in Figures 27 and 28 for the 1981 and 1982 summer sampling periods. Occupied water temperatures ranged from 5-22°C with mean temperatures of 14.1 $\pm$ 4.1°C (CPUE=13.9°C) in 1981 and 12.2 $\pm$ 3.9°C (CPUE=11.2°C) in 1982. Upon initial inspection, the 1982 temperature distribution seemed considerably lower than that of 1981. This difference is largely the result of the single day's netting on July 29 (see Fig. 26) which produced 58% of the total 1982 summer sample and effectively shifted the total temperature distribution toward the lower range. A t-test of brown trout temperatures between 1981 and 1982 captures indicated no significant differences (p=0.052) in mean temperature between the two summer sampling periods. This relatively large

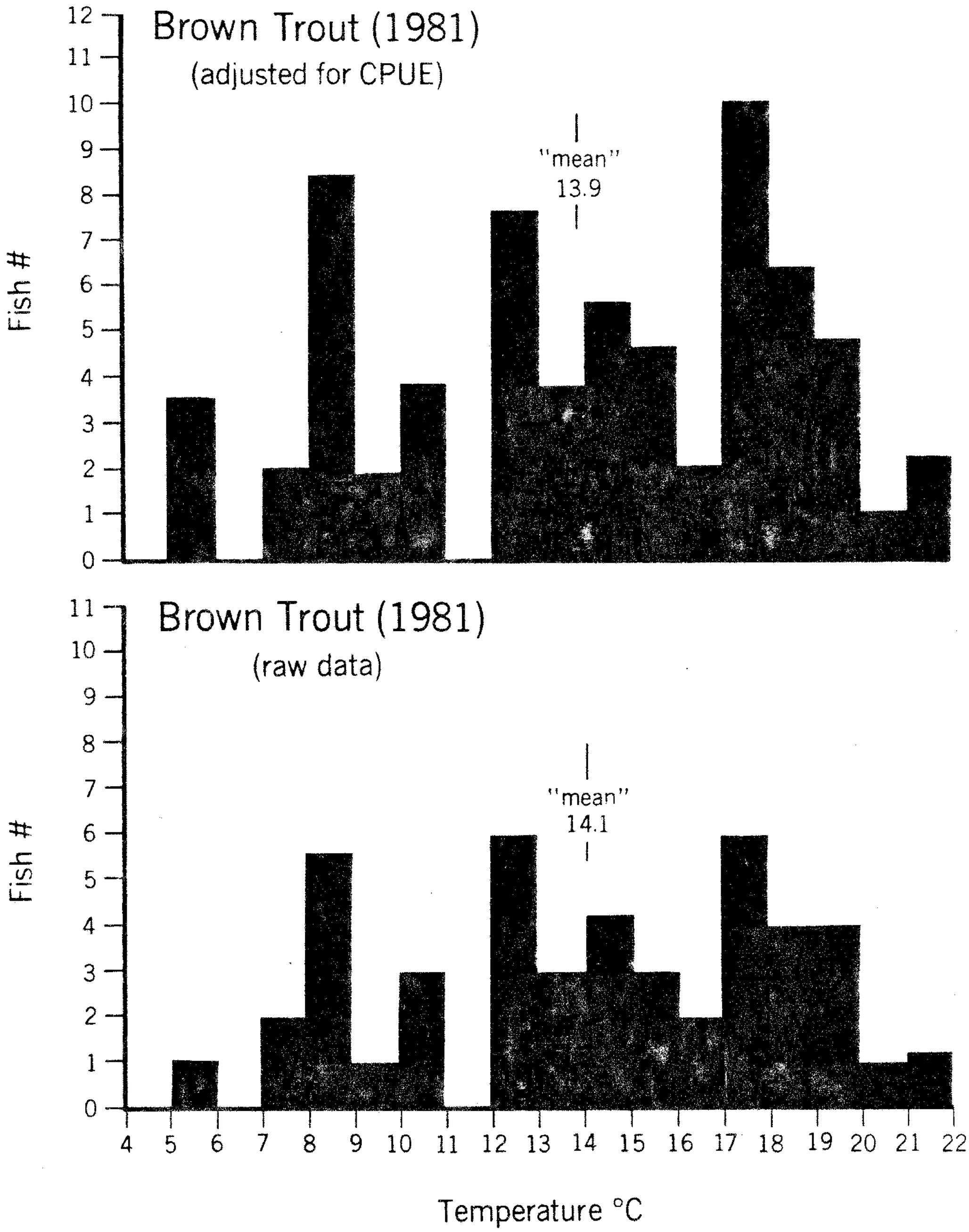


Fig. 27. Summer 1981 brown trout temperature distribution as determined from vertical gill netting.

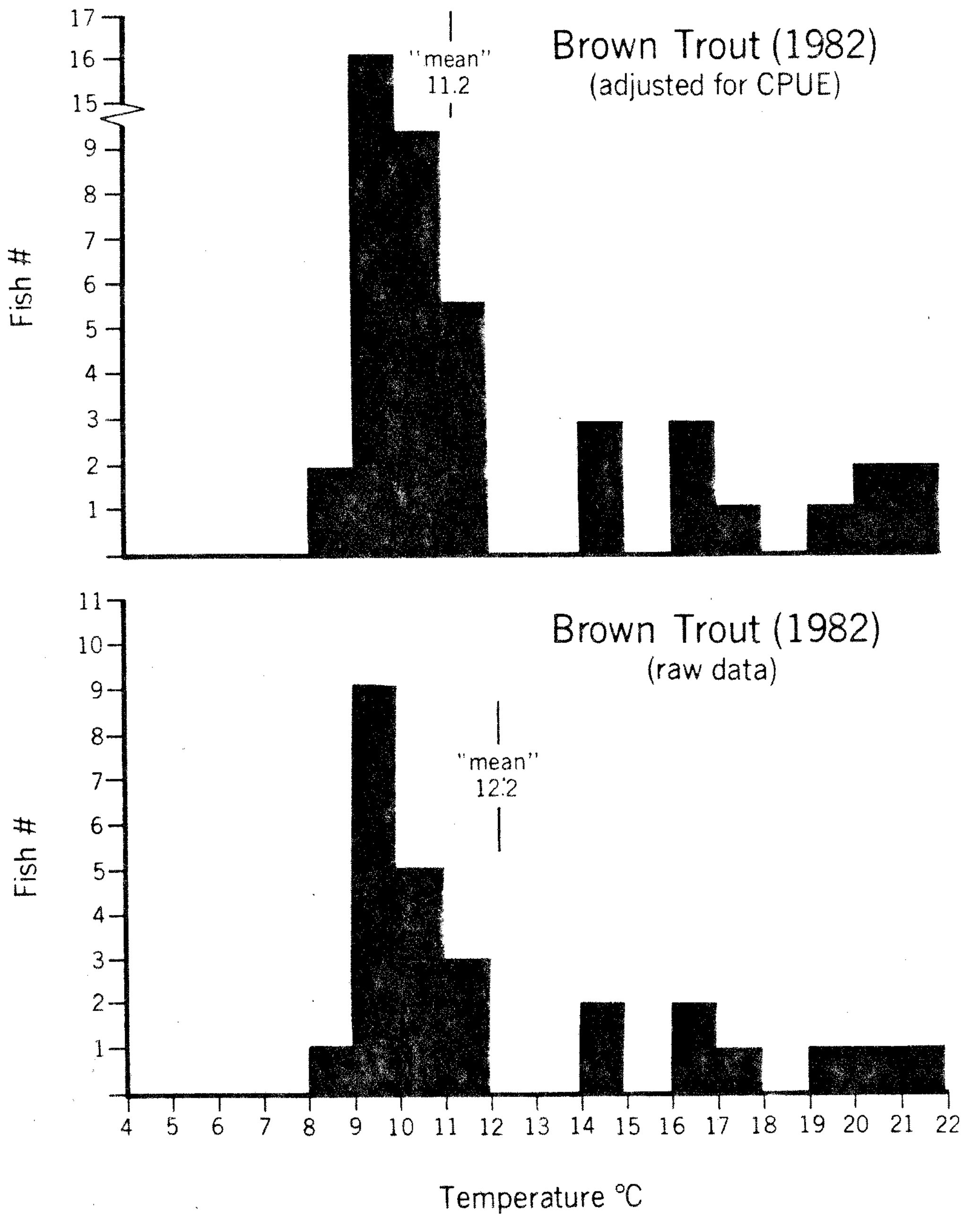


Fig. 28. Summer 1982 brown trout temperature distribution as determined from vertical gill netting.

catch was largely the result of an encounter of nets with the intersection of the thermocline and bottom. Near misses of the same sort in 1981 also produced increased catches in horizontal bottom nets, but due to the larger 1981 sample and horizontal net conversion these factors did not bias the results to such a large degree. Despite the influence of that single 1982 sample, I suggest, based upon the larger more representative 1981 sample, that Lake Ontario brown trout exhibit no distinct summer temperature preferences within the 8-18°C range.

Although previous studies by Reynolds and Casterlin (1979) and Abraham (1979) report relatively narrow ranges of brown trout water temperature preference (10.3-13.7°C, and 10-15°C, respectively), my data supports a wider range of water temperature preference in Lake Ontario. However, mean preferred temperatures in these studies are strikingly similar ranging from 11.2 to 13.9°C. Seventy-eight percent (78%) of the combined summer samples were caught in the 8-18°C range, and 81% of combined spring, summer and fall brown trout temperatures were in the 8-18°C range. Higher and lower temperatures of brown trout occupancy (19%) occurred largely during nearshore periods when the 8-18°C range was not available for selection. Pursuit of food and observed thermoclinal zone rocking may be at least partly responsible for temperatures occupied outside the 8-18°C range in summer. The 8-18°C temperature range also encompasses the 8-11°C temperature range of maximum gross efficiency of brown trout energy utilization reported by Elliot (1976).

Because depth of capture alone revealed no pronounced summer brown trout habitat clues other than the deeper movement of brown trout as the lake warmed in summer (see Figs. 25 and 26), individual brown trout positions in the water column were plotted relative to the only discernable physical structures in the pelagic regions of the lake: the thermoclinal zone and the lake bottom (Figs. 29 and 30). Regression lines are provided to illustrate that CPUE conversions had little effect on distributions relative to the thermoclinal zone. As is clearly seen, brown trout concentrated within and near the thermoclinal zone. In 1981, 49% of the brown trout sample was caught within the thermoclinal zone and 27% were within ±3m of that zone. In 1982 the relationship was much the same with 80% of the sample within the thermoclinal zone and 12% within ±3m. The 1982 data, however, shows a pronounced brown trout affinity for the lake bottom, again an artifact of the single 1982 sample caught at the intersection of bottom and the thermoclinal zone, while the 1981 sample does not.

Because mean thermoclinal zone depths ranged from 2-35m and mean thermoclinal zone temperatures (averages of upper and lower limits) ranged from 8.3 to 18.8°C over the combined summer sampling periods, attraction to the thermoclinal zone cannot be attributed to specific depths or temperatures. Thus, some characteristic(s) of the zone of rapid temperature change must provide the attraction. Lichorat (1982) found a similar salmonid preference for thermoclinal areas of the water column during a vertical gill netting study on Lake Erie, but he did not provide specific data on brown trout.

As discussed earlier, during nearshore movements brown trout were attracted to thermal plumes from natural and power station outflows. Fishermen have also met with considerable success in power station warm water discharges in winter. In sum, Lake Ontario brown trout appear to show preference for areas of rapid temperature change regardless of

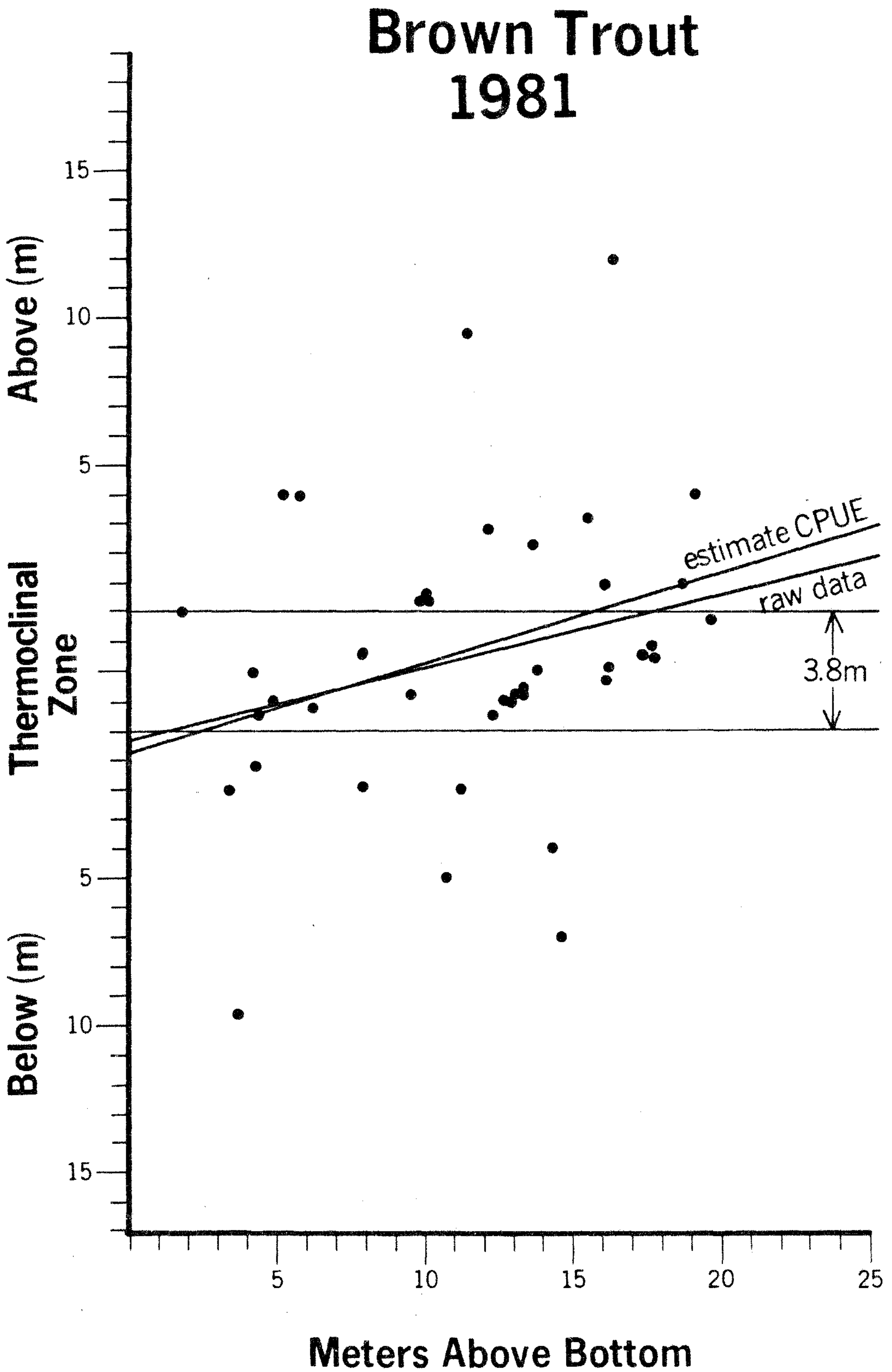


Fig. 29. Brown trout capture positions relative to the thermoclinal zone and bottom (1981).

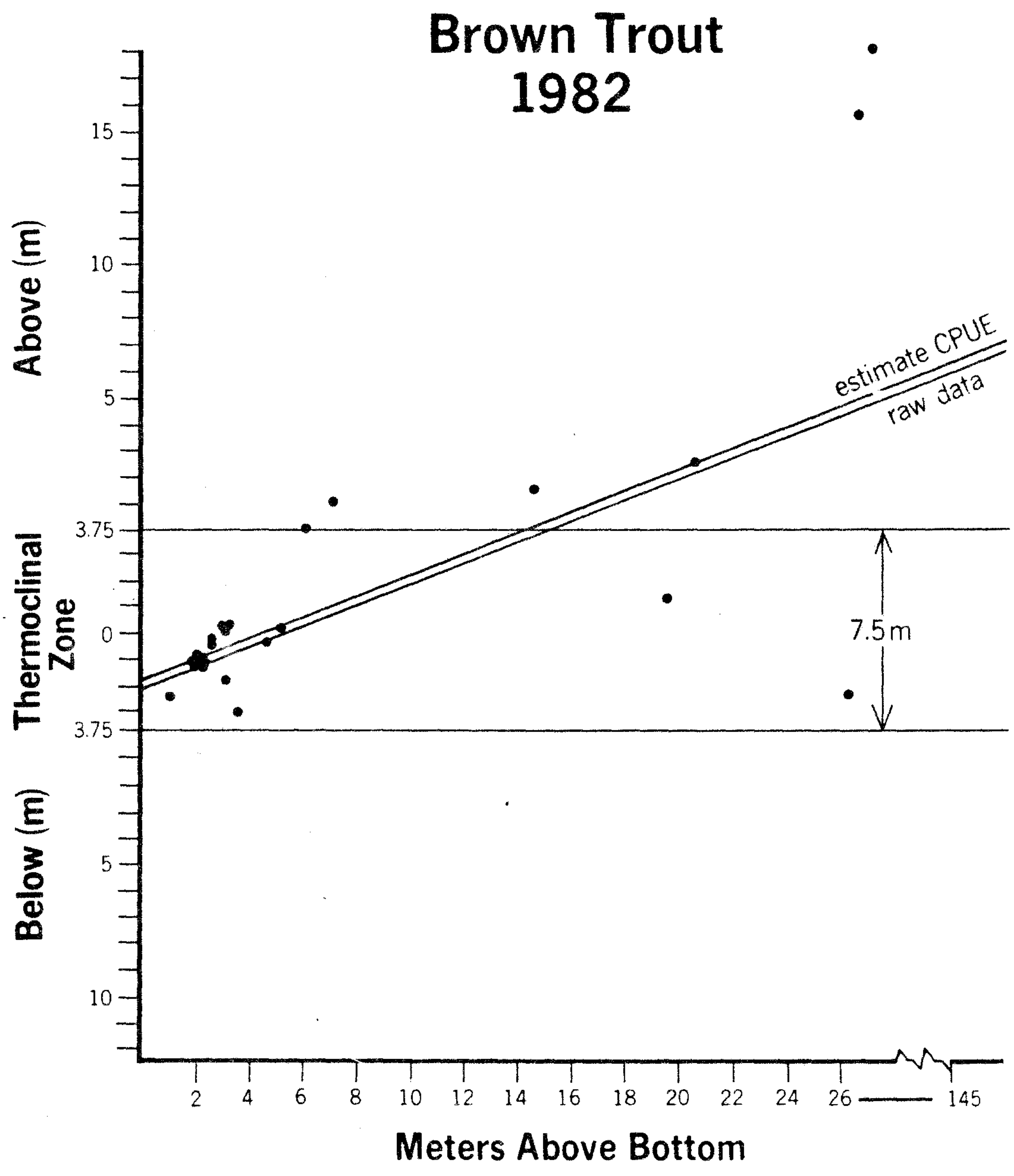


Fig. 30. Brown trout capture positions relative to the thermoclinal zone and bottom (1982).

season, absolute temperature (within 8-18°C), or depth. Brett (1971) concluded that sockeye salmon exhibit a diel vertical migration pattern of energetics regulation through thermoregulation. Zones of rapid temperature change, whether they are thermal plumes in spring, fall, and winter or thermoclinal areas of the water column in summer, could provide brown trout the same bioenergetic efficiency by migrating in and out of thermal structure to augment food conversion efficiency.

Brown trout food fish preference

Only alewife (*Alosa psuedoharengus*) and rainbow smelt (*Osmerus mordax*) were identified in Lake Ontario brown trout stomachs during the 1981,82 sampling seasons. A total of 127 stomachs were analyzed for contents from July 2 to September 3, 1981, and from April 17 to September 11, 1982. Stomach contents were sorted according to species and unidentifiable partially digested remains. Forty-five stomachs were empty and 30 contained only unidentifiable remains. Alewives were identified in 40 and smelt in 8 stomachs. Only alewives were identified in spring (before summer stratification) brown trout stomachs which were sampled from April 17 to July 2, 1982. Interestingly, smelt were only identified in brown trout stomachs from July 7 to July 20, 1981, and July 5 to July 23, 1982.

Percentages by volume were recorded according to stomach content categories. Percentages were totaled and averaged for each forage fish species. Stomach contents for summer samples were strikingly similar and contained 49% alewife, 9% smelt, and 42% unidentified remains in 1981 and 1982 combined. Spring 1982 brown trout stomachs contained 66% alewife and 34% unidentified remains. Clearly, alewives hold a very high importance value for brown trout in Lake Ontario, while other potential food sources were neglected, except rainbow smelt which were consumed in mid-July.

Lake Ontario forage fish data collected in conjunction with this study (Olson, in preparation) was organized by vertical distribution in relation to the thermoclinal zone (Figs. 31 and 32) and occupied temperatures in an effort to evaluate the influence, if any, of forage fish upon the brown trout vertical distribution. Note in Figure 31 that the 1982 alewife vertical distribution is concentrated within and above the thermoclinal zone, as were brown trout distributions, although alewife tended to utilize much more of the warmer water habitat above the thermoclinal zone. The alewife temperature preference ($18.1 \pm 3.9^{\circ}$) illustrates the high temperature tolerance of Lake Ontario alewife as opposed to the lower temperature preference of smelt ($9.3 \pm 1.7^{\circ}C$). Note that the smelt vertical distribution lies predominantly within and below the thermoclinal zone (see Fig. 32). These data indicate habitat partitioning among smelt and alewife. However, 81% of the smelt plotted in and above the thermoclinal zone occupied that area of the water column during the month of July. July was the only time from April to September that brown trout stomachs were found to contain smelt. Apparently, sufficient numbers of smelt become available for brown trout predation only when they move upward into brown trout habitat in July.

Summer netting applications to the fishery

Summer angling for salmonids has typically been frustrating to Lake Ontario anglers, who have depended largely upon luck and depth sounders to locate and catch salmonids. With the expenditure of funds generated

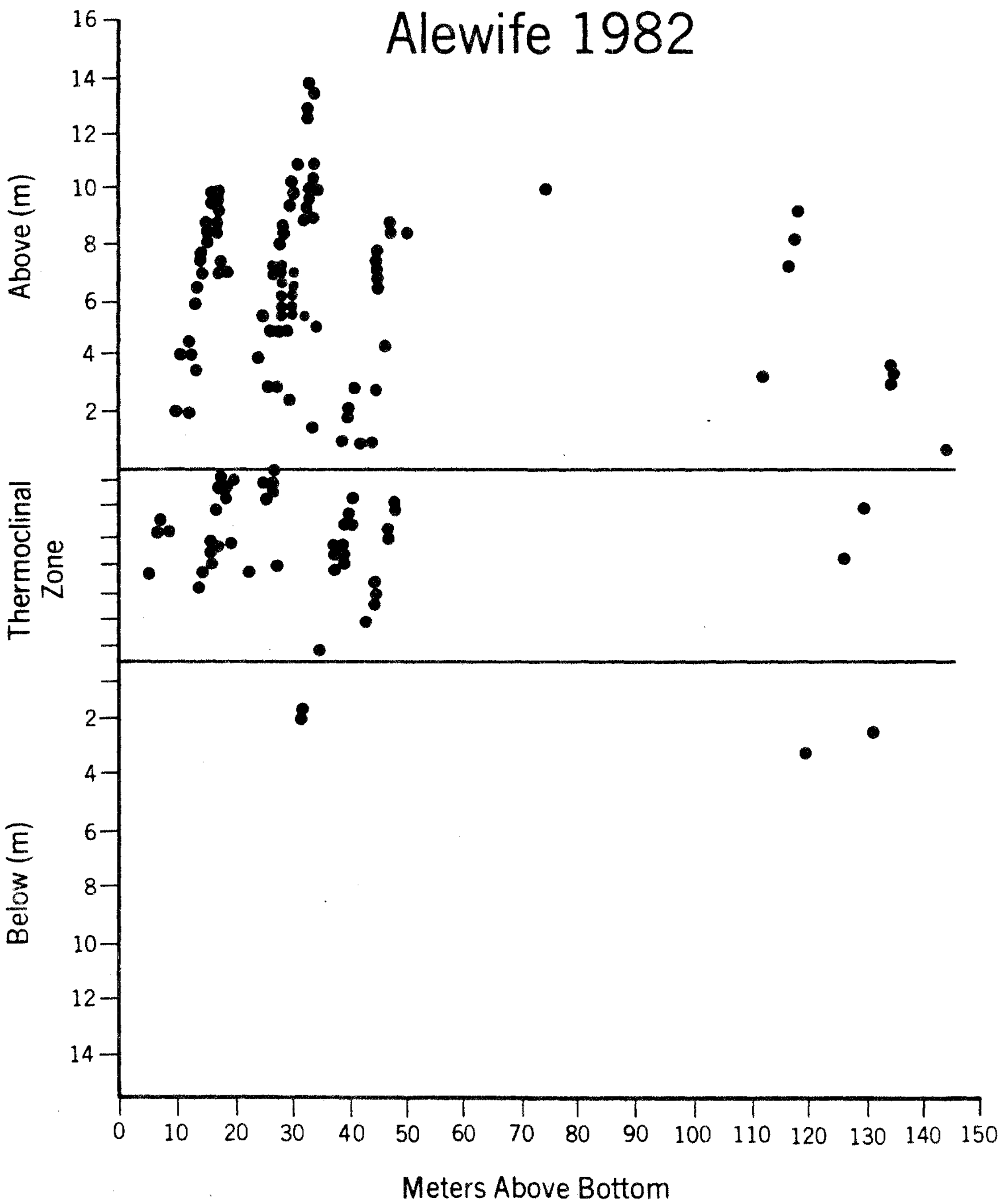


Fig. 31. Alewife capture positions relative to the thermoclinal zone and bottom (1982).

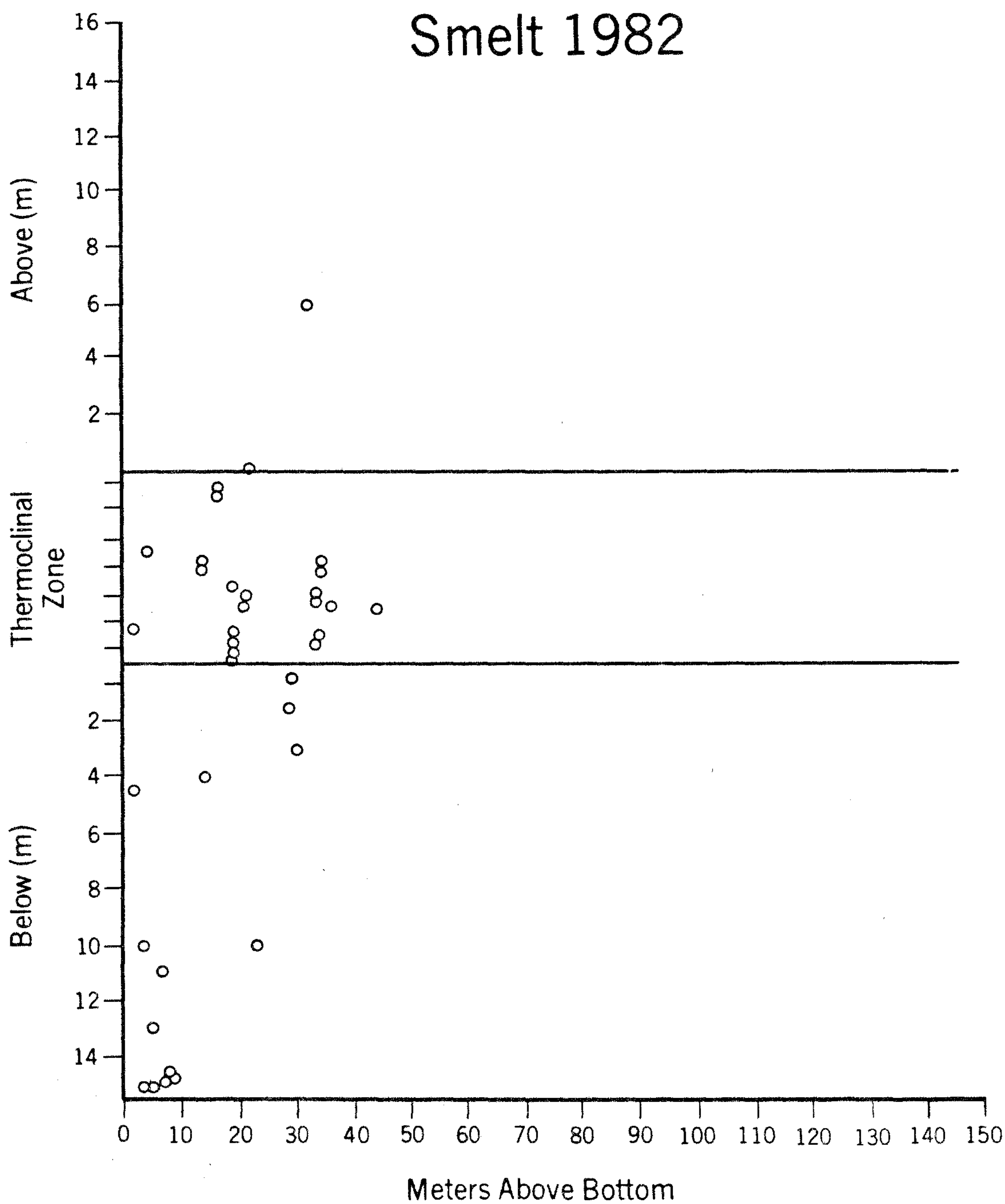


Fig. 32. Rainbow smelt capture positions relative to the thermoclinal zone and bottom (1982).

by tax dollars and license fees that have led to the highly successful Lake Ontario salmonid fishery, a maximized angler harvest of adult fish would prove an efficient use of a largely "put and take" fishery. By actively seeking out thermoclinal areas of the summer water column, particularly near the intersection of the thermoclinal zone and bottom, downrigger-equipped anglers could significantly increase their summer Lake Ontario brown trout harvest while improving their opportunity for catching other salmonids as well (Olson, in preparation). By shifting emphasis from depth sounders to a temperature probe system of some type, anglers could identify preferred fish habitat in a quick and efficient manner. With a temperature probe, anglers could seek out the 8-18°C temperature preference range of brown trout as well as locate thermoclinal regions of the stratified summer water column.

Preferred Lake Ontario brown trout summer vertical distribution might be defined even more accurately in the future using strict day verses night vertical gill netting to evaluate possible vertical migrations within the water column.

Management concerns

An alternative explanation for brown trout presence in predominantly nearshore areas less than 32m deep would be apparent competition potential and habitat partitioning among brown trout and other Lake Ontario salmonids. Data gathered in conjunction with this study (Olson, in preparation) suggests that summer thermal and vertical partitioning occurs in Lake Ontario, though there is considerable species overlap in preferred areas of the water column. Thermal habitat partitioning by fishes has also been reported in Lake Michigan (Crowder and Magnuson

1982; Brandt *et al*. 1980). Although vertical and thermal partitioning does appear to occur among Lake Ontario salmonids, salmonid catches over the deeper standard depths ($\geq$47m) were considerably smaller (Olson, in preparation) than nearshore catches, indicating that potential for salmonid competition is probably greater nearshore than offshore.

The lack of specific knowledge concerning habitat partitioning, potential competition, and food resource limits of the Lake Ontario ecosystem is cause for some concern. The management strategy at present is based upon the number of salmonids planted yearly in Lake Michigan. Because Lake Ontario is roughly 1/3 the size of Lake Michigan, the stocking effort is geared to 1/3 the number of salmonids stocked in Lake Michigan (Eckert, personal communication). The results of this and other studies indicate that though there is much water in Lake Ontario, several salmonid species are selectively squeezing themselves into thermoclinal areas nearshore and are utilizing (competing for?) the same food resources in summer.

Specific information concerning the population dynamics and trophic relations in Lake Ontario fishes is necessary to define the salmonid carrying capacity in Lake Ontario and avoid potential problems that may occur with increased stocking. Though current information on Lake Ontario fish stocks shows that the salmonid stocking effort to date is doing very well (Bureau of Fisheries Lake Ontario Unit 1983), timely additional research into species interactions, habitat availability and forage fish dynamics may prevent future problems.

SUMMARY

Radio-tagged brown trout initially moved eastward with shore currents and showed preference for stocking sites in fall and contrasting water temperatures at natural and artificial outflow areas in spring and fall. Spring surgically tagged brown trout exhibited longer eastward movements, probably due to an extended recovery period after tagging. When fully recovered, brown trout exhibited east/west movement reversals in spring and fall.

During spawning seasons, females exhibited significantly longer movements than males. Homing behavior was pronounced in fall, but no radio-tagged brown trout reached stream habitat suitable for spawning. Correlation analyses revealed significant inverse relationships between nearshore turbidity levels and tracking success in spring and fall. Tracking success was high when nearshore water temperatures were 8-18°C. Temperature-sensing transmitters related ambient brown trout water temperatures of 3.6-19.9°C during nearshore occupancy, but fish were rarely recorded in waters cooler than 8°C or warmer than 18°C when the 8-18°C range was available for selection. Radio-tagged brown trout vacated fall nearshore waters for warmer 4°C offshore waters where they apparently over-winter. Spring nearshore waters were vacated for cooler, deeper, offshore waters where brown trout spend the summer.

Vertical gill netting during summer showed brown trout to prefer thermoclinal regions of the water column within 5km of shore, regardless of absolute thermoclinal zone temperature or depth. The brown trout catch was particularly high at the intersection of the thermocline and

bottom. No brown trout were caught over depths greater than 47m. Brown trout showed no distinct summer temperature preference between 8-18°C. Given preferred thermal conditions, brown trout prefer to be as close to shore as possible.

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Appendix 1. Fall radio-tagged brown trout lake movements.

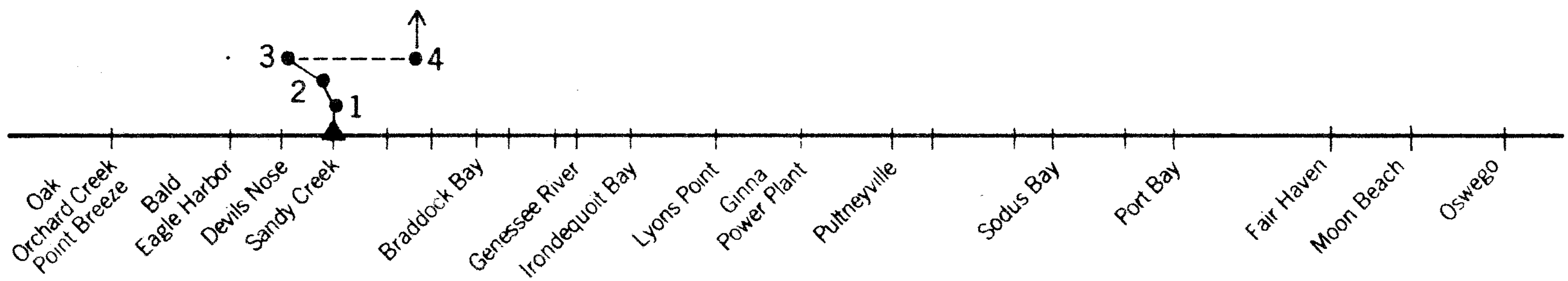
6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

- - - - Period of Lost Contact

Radio #: 170



Location	Dates
▲	9/30/80
1	10/1/80
2	10/2/80
3	10/3/80
4	10/24/80

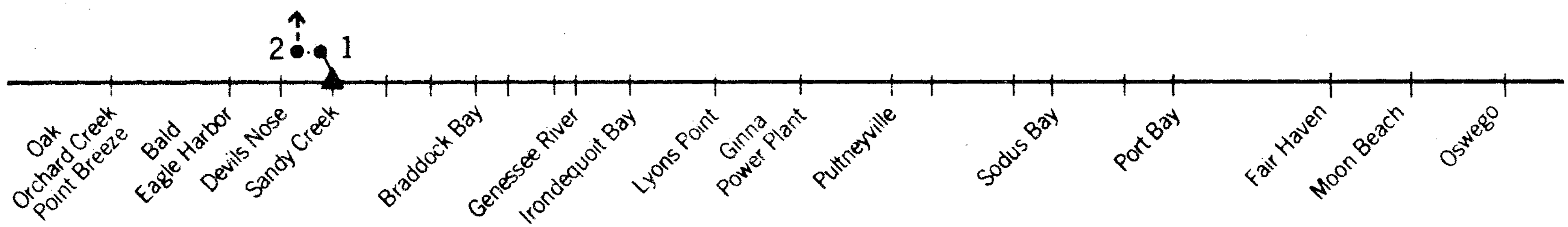
6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

---- Period of Lost Contact

Radio #: 210 B



Location	Dates
▲	11/8/80 → 11/10/80
1	11/11/80
2	11/15/80 → 11/24/80

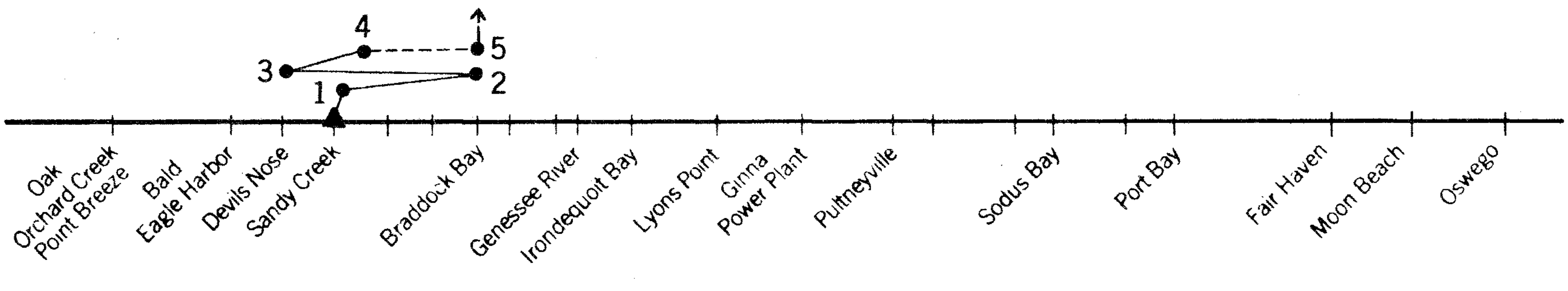
6.2 Kilometers

▲ Location of Capture, Tagging, Release

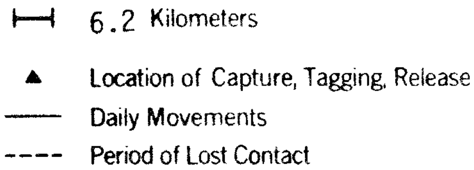
—— Daily Movements

---- Period of Lost Contact

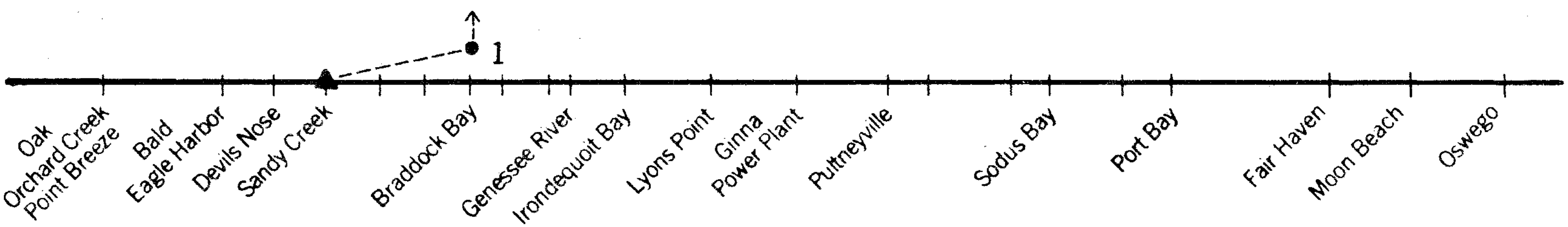
Radio #: 270



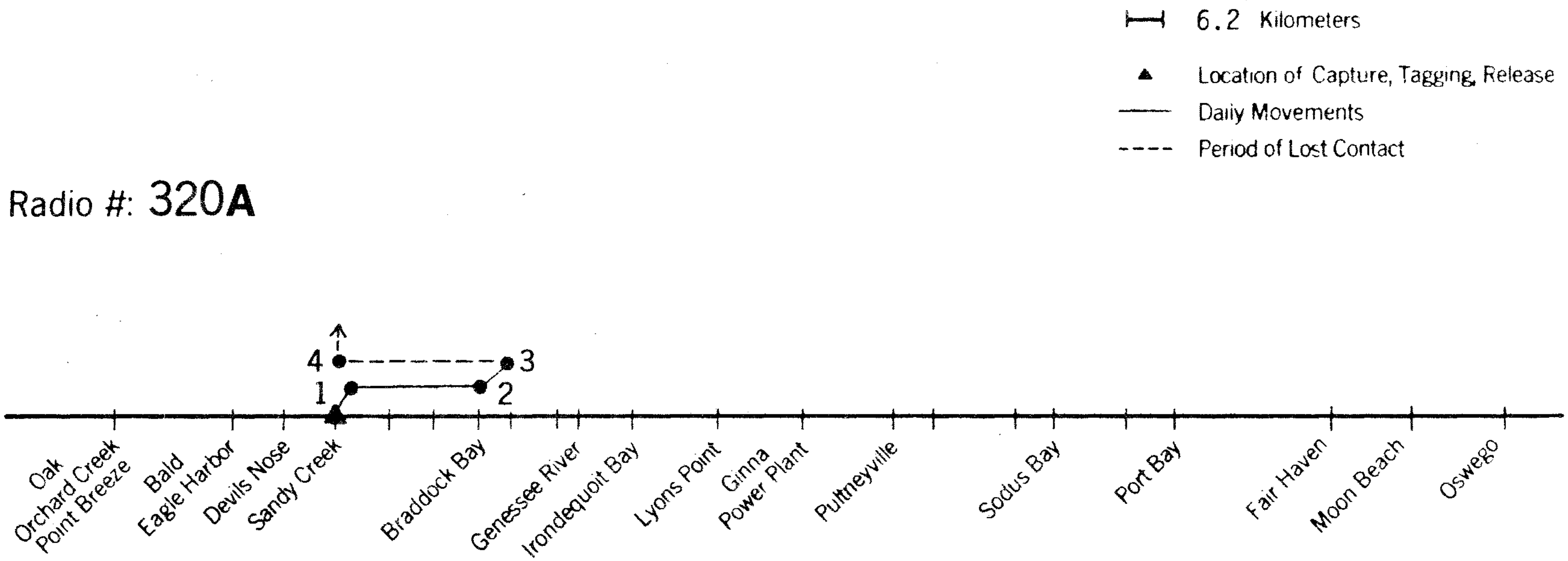
Location	Dates
▲	10/8/80
1	10/8/80
2	10/9/80
3	10/10/80
4	10/13/80
5	10/24/80



Radio #: 290

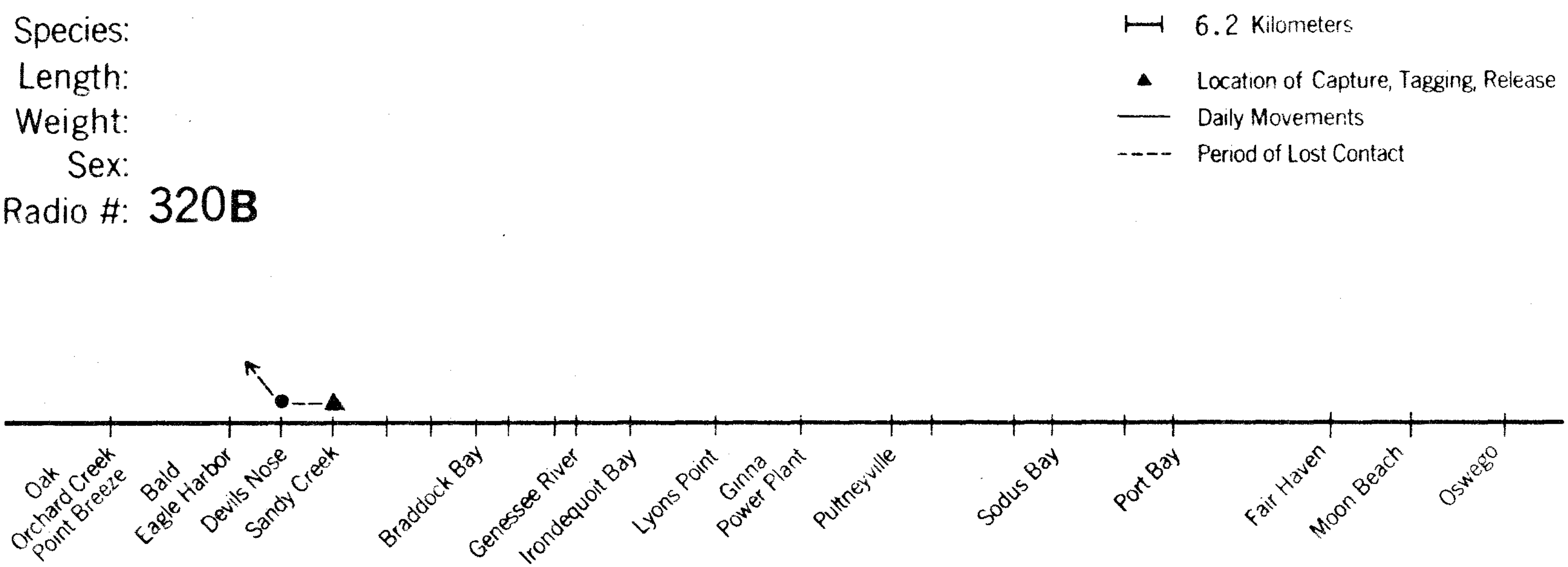


Location	Dates
▲	1/8/80 ⟶ 11/9/80
1	11/13/80



Location	Dates
▲	10/22/80
1	10/22/80
2	10/23/80
3	10/28/80
4	11/8/80

Species:
Length:
Weight:
Sex:
Radio #: **320B**



Location	Dates
▲	9/22 ⟶ 9/29/81
1	10/27 ⟶ 10/28/81

Appendix 2(A). Lake movements of spring radio-tagged brown trout that remained active during the study period.

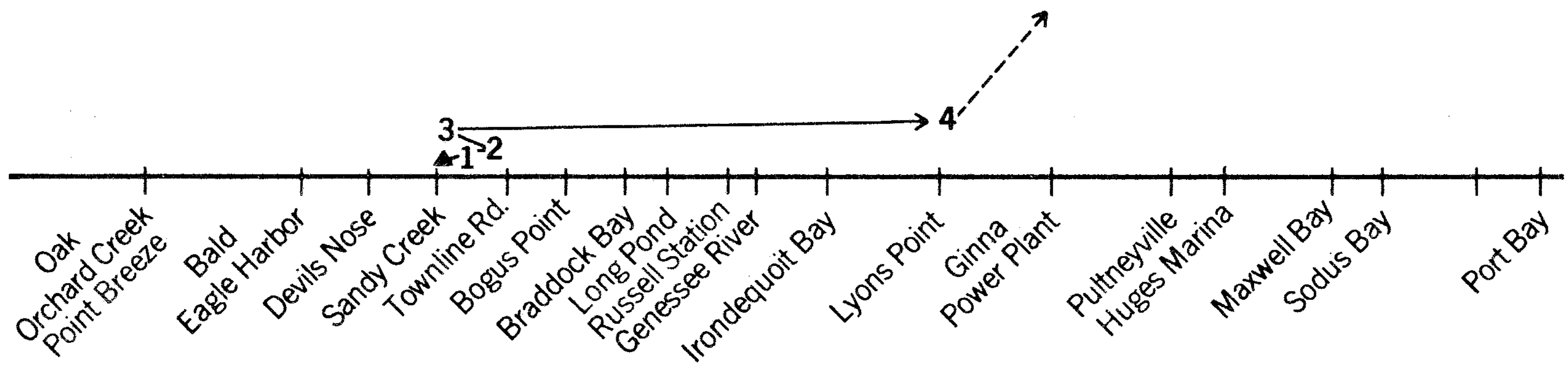
6.2 Kilometers

▲ Location of Capture, Tagging, Release

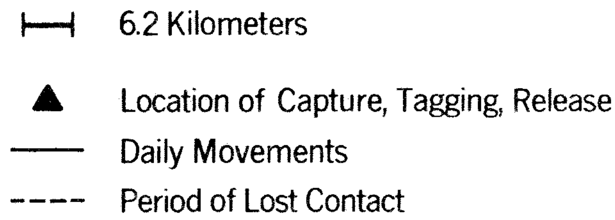
—— Daily Movements

- - - - Period of Lost Contact

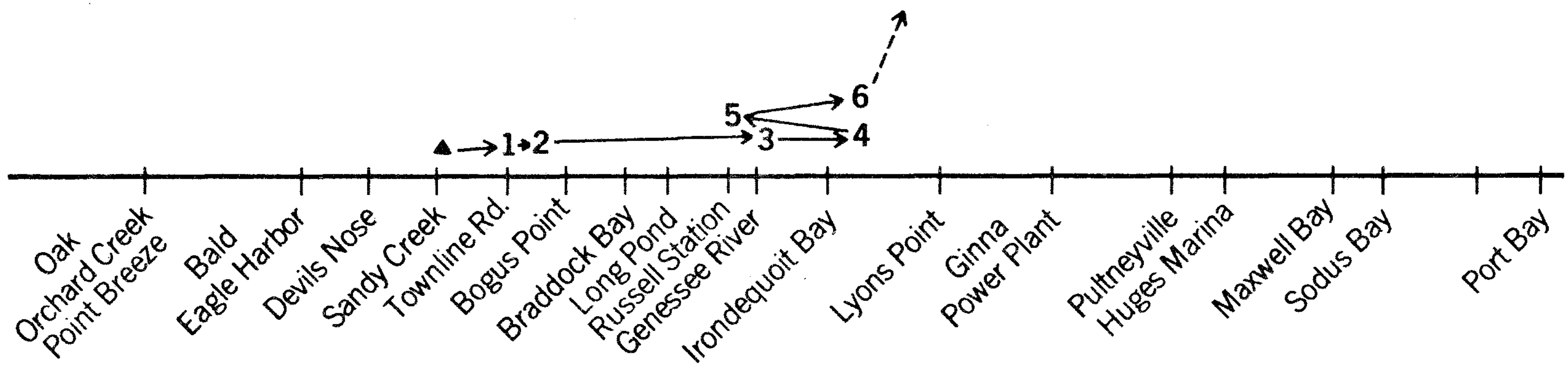
Radio #: 540B



Location	Dates
▲	5/22/81
1	5/24/81
2	5/25/81
3	5/28/81 ⟶ 6/05/81
4	6/08/81



Radio #: 570



Location	Dates
▲	4/21/81
1	4/23/81
2	4/24/81
3	4/25/81
4	4/26/81 → 4/28/81
5	4/30/81
6	5/02/81

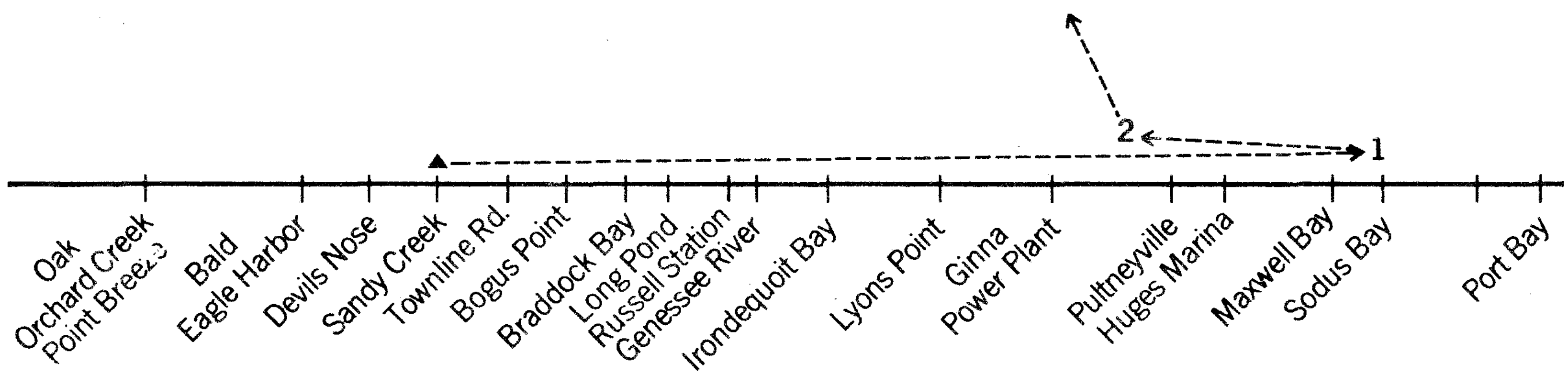
6.2 Kilometers

▲ Location of Capture, Tagging, Release

——— Daily Movements

- - - - Period of Lost Contact

Radio #: 580



Location	Dates
▲	4/21/81
1	4/30/81
2	5/04/81

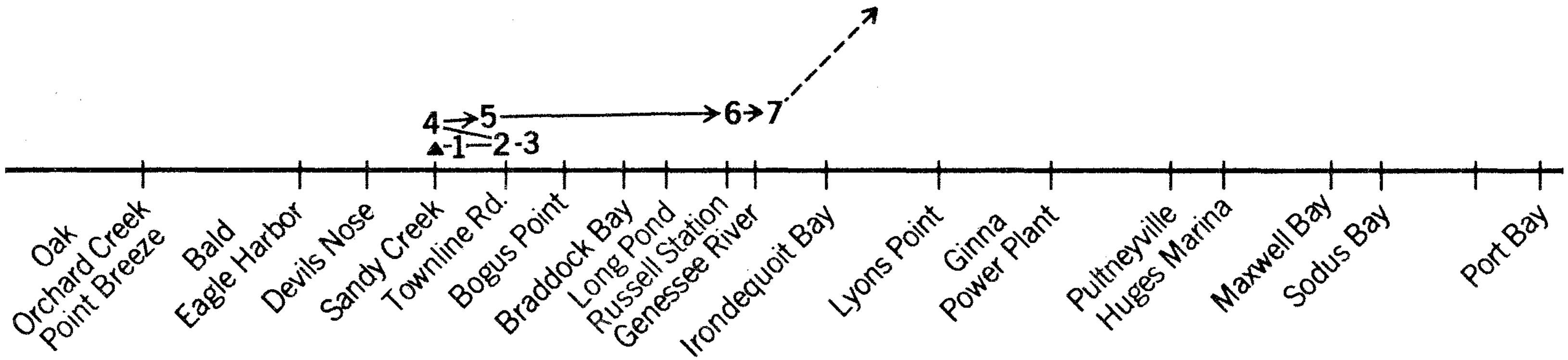
6.2 Kilometers

▲ Location of Capture, Tagging, Release

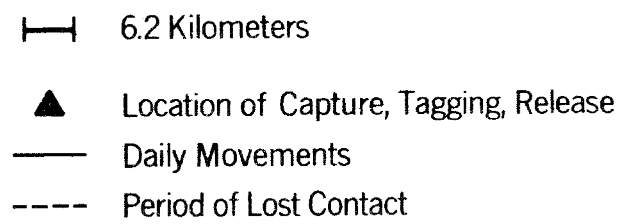
—— Daily Movements

---- Period of Lost Contact

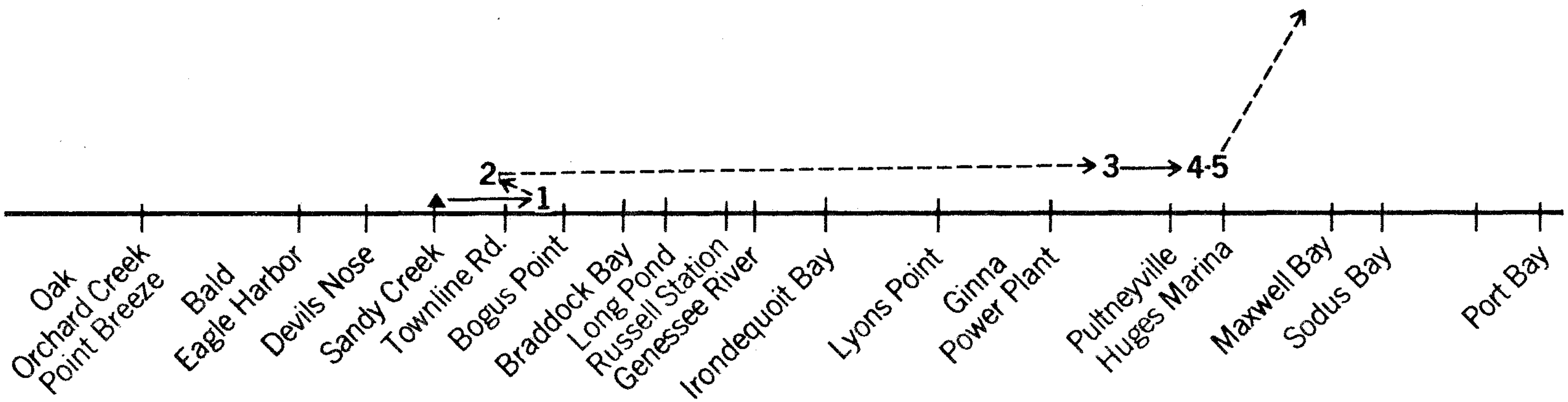
Radio #: 620



Location	Dates
▲	5/03/81
1	5/03/81
2	5/04/81
3	5/05/81
4	5/06/81
5	5/08/81
6	5/09/81 ⟶ 6/06/81
7	6/08/81

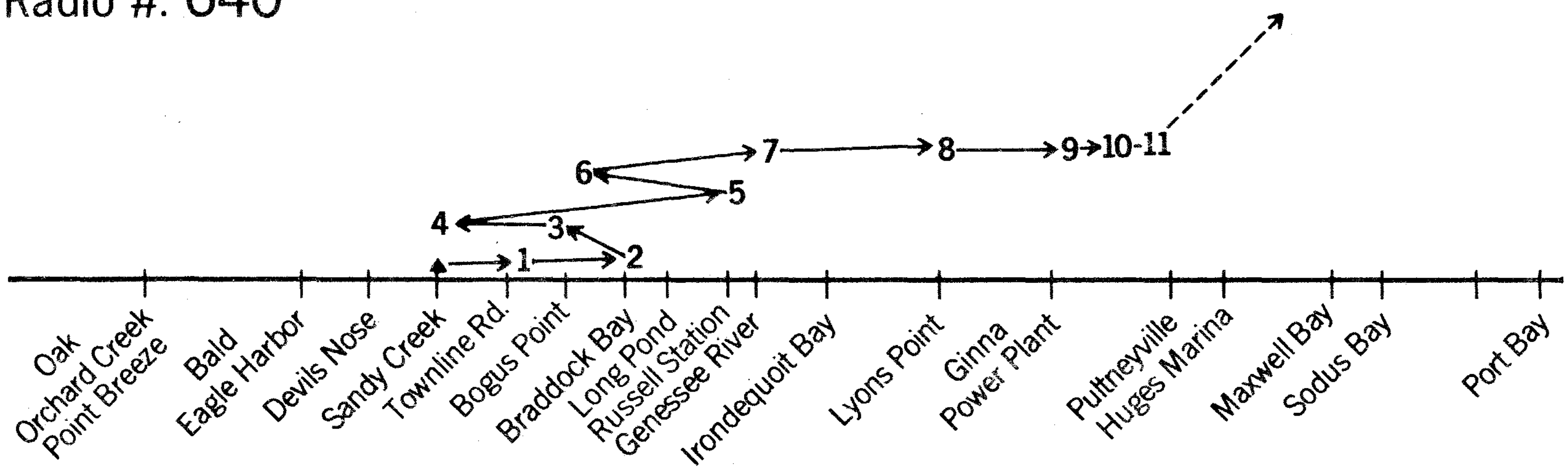


Radio #: 630



Location	Dates
▲	4/16/81 ⟶ 4/17/81
1	4/18/81
2	4/22/81
3	4/26/81
4	4/30/81 ⟶ 5/13/81
5	5/25/81

Radio #: 640



Location	Dates
▲	5/22/81
1	5/24/81
2	5/25/81
3	5/26/81
4	5/29/81 → 5/30/81
5	5/31/81
6	6/01/81
7	6/02/81
8	6/03/81
9	6/04/81
10	6/06/81 → 6/10/81
11	6/08/81

├─┤ 6.2 Kilometers

▲ Location of Capture, Tagging, Release

——— Daily Movements

- - - - Period of Lost Contact

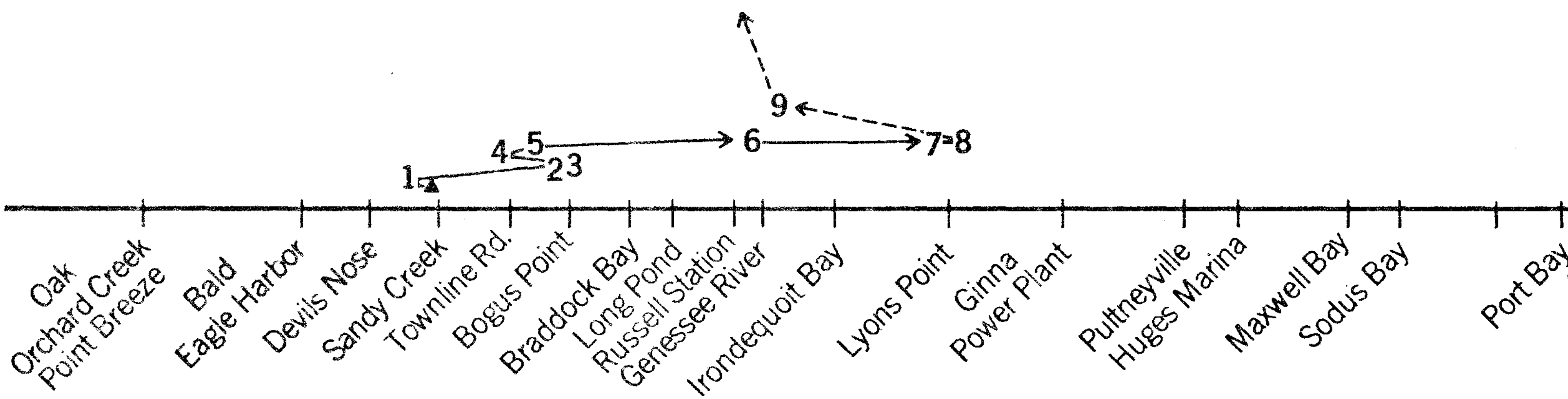
6.2 Kilometers

▲ Location of Capture, Tagging, Release

——— Daily Movements

- - - - Period of Lost Contact

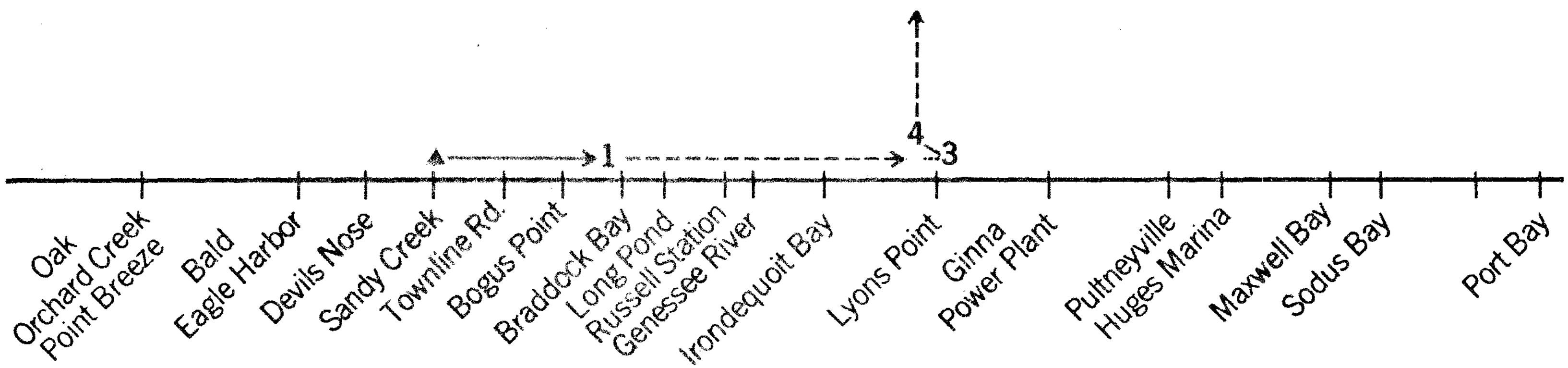
Radio #: 670B



Location	Dates
▲	5/22/81
1	5/24/81
2	5/25/81
3	5/26/81
4	5/28/81 ⟶ 5/30/81
5	5/31/81
6	6/01/81
7	6/03/81
8	6/06/81 ⟶ 6/12/81
9	6/15/81

6.2 Kilometers
▲ Location of Capture, Tagging, Release
—— Daily Movements
---- Period of Lost Contact

Radio #: 700



Location	Dates
▲	5/04/81 ⟶ 5/05/81
1	5/06/81
2	5/10/81 ⟶ 5/13/81
3	5/18/81 ⟶ 5/20/81
4	5/22/81

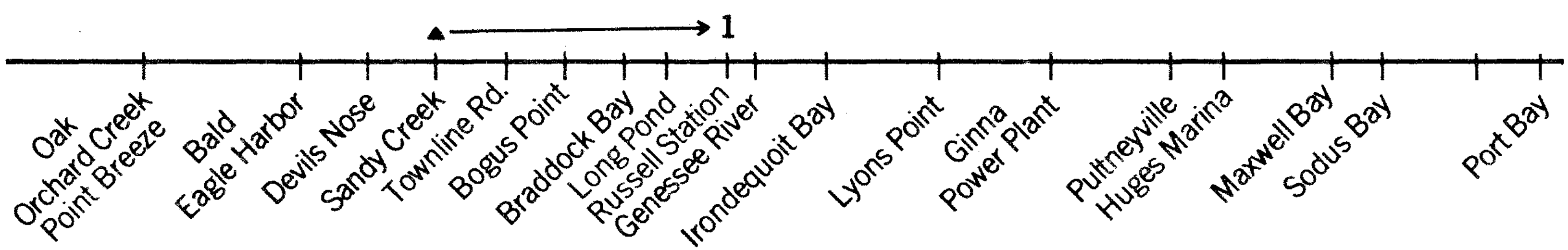
Radio #: 710

6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

---- Period of Lost Contact



Location	Dates
▲	4/20/81 ⟶ 4/23/81
1	4/25/81 ⟶ 4/26/81

May have been caught during
April Fishing Derby

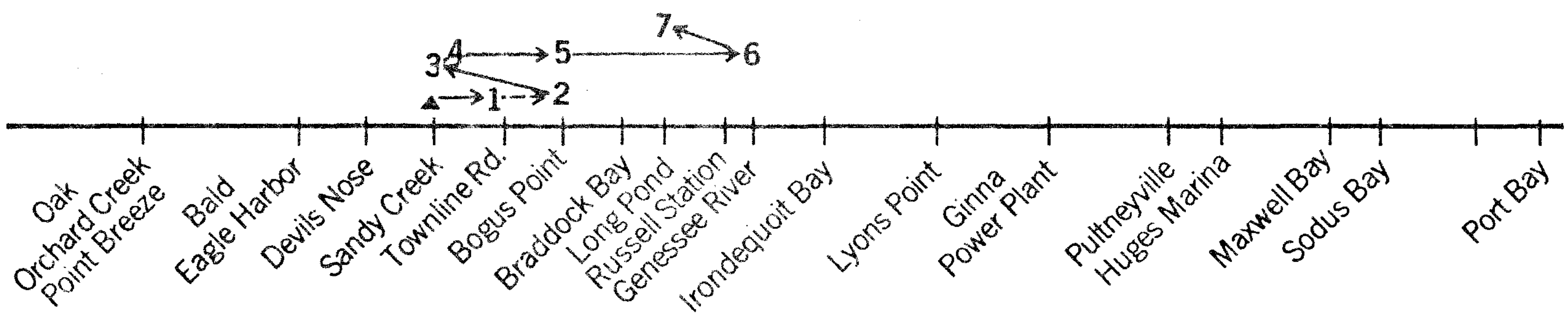
Radio #: 740

6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

---- Period of Lost Contact



Location	Dates
▲	4/16/81
1	4/17/81
2	4/25/81 → 4/26/81
3	4/28/81 → 4/30/81
4	5/02/81 → 5/03/81
5	5/04/81
6	5/06/81 → 5/08/81
7	5/09/81 → 7/14/81

Appendix 2(B). Lake movements of spring radio-tagged brown trout that died during the study period.

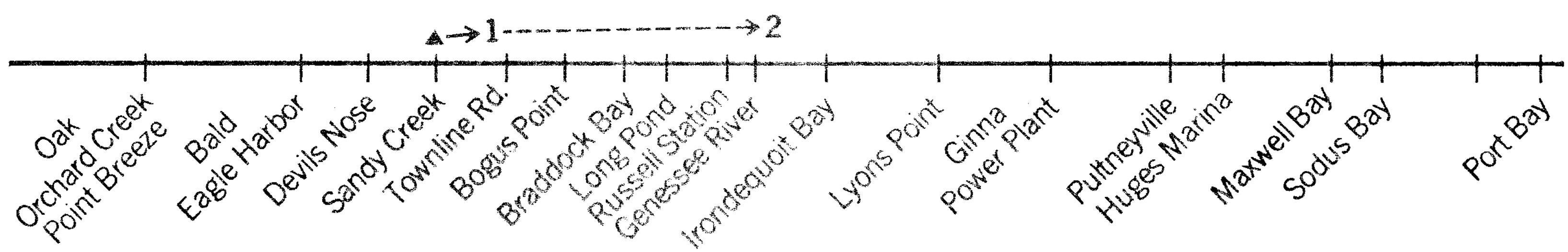
|—| 6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

- - - - Period of Lost Contact

Radio #: 510



Location	Dates
▲	4/15/81
1	4/17/81
2	5/10/81 ⟶ 7/14/81

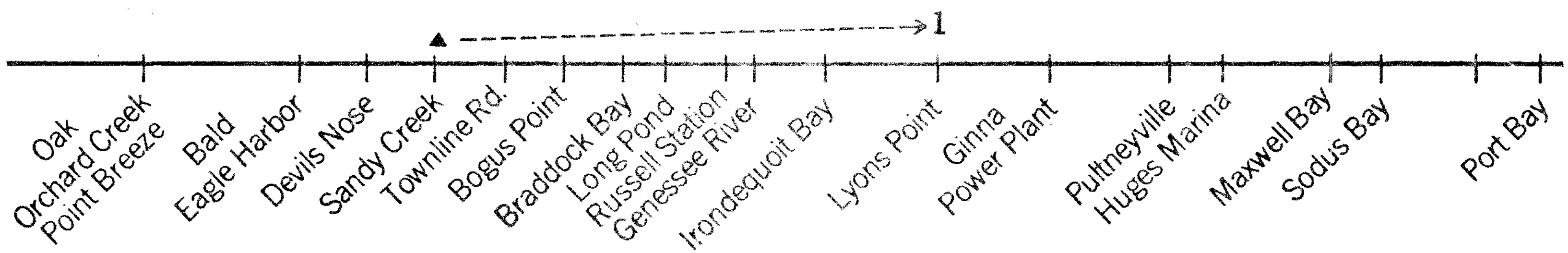
Radio #: 550

6.2 Kilometers

▲ Location of Capture, Tagging, Release

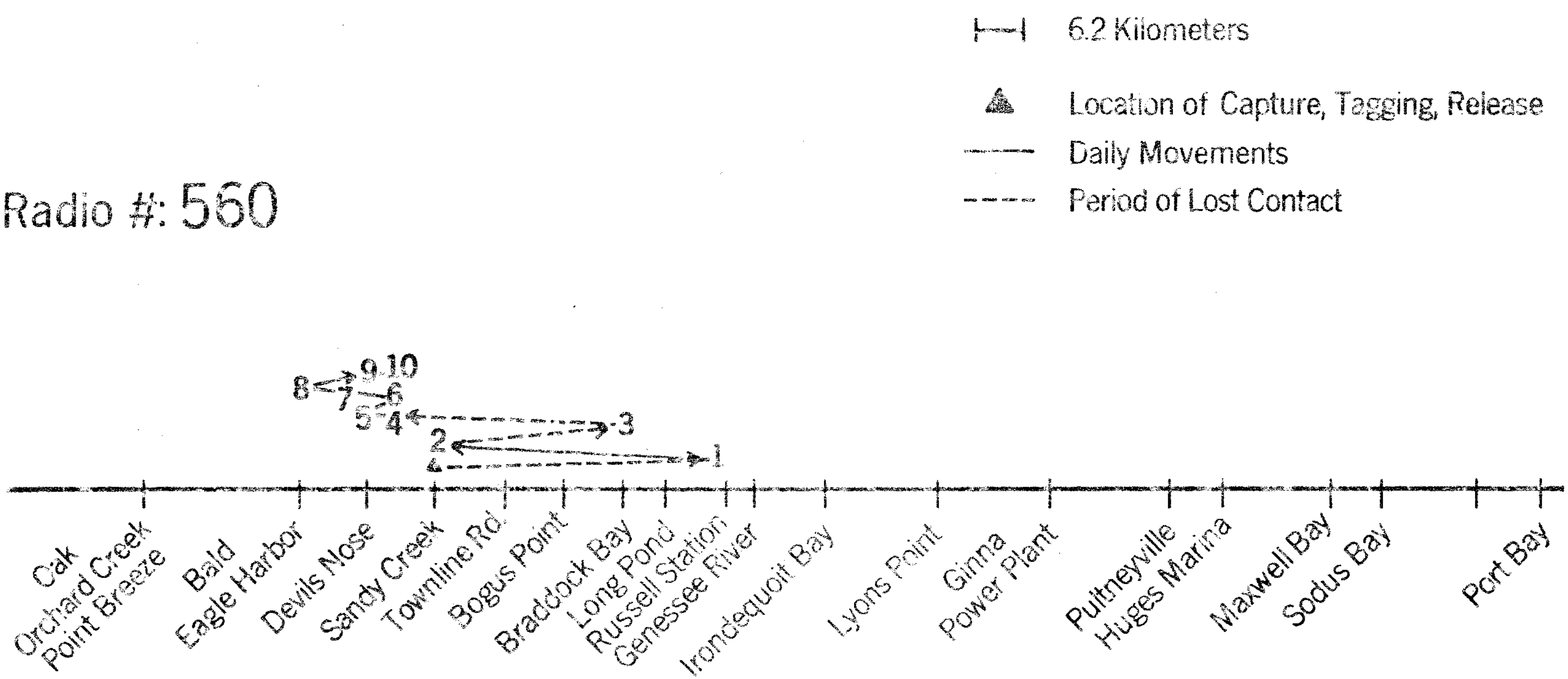
—— Daily Movements

---- Period of Lost Contact



Location	Dates
▲	4/18/81 → 4/20/81
1	4/26/81 → 7/14/81

Radio #: 560



Location	Dates
▲	4/18/81
1	4/22/81
2	4/23/81
3	4/28/81
4	5/02/81
5	5/04/81 ⟶ 5/05/81
6	5/08/81
7	5/09/81
8	5/10/81
9	5/13/81
10	5/18/81 ⟶ 6/05/81
	Fish found dead on beach

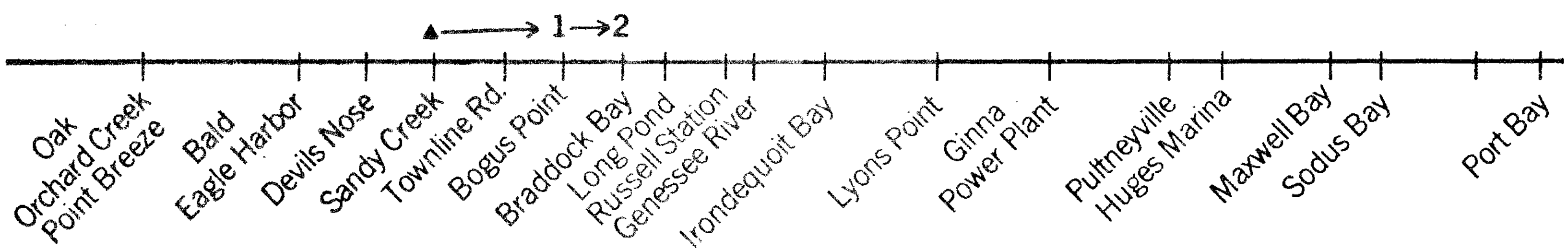
Radio #: 610

6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

---- Period of Lost Contact



Location	Dates
▲	4/21/81
1	4/23/81
2	4/25/81 ⟶ present

Fish died or caught;
transmitter remains
in Braddock Bay

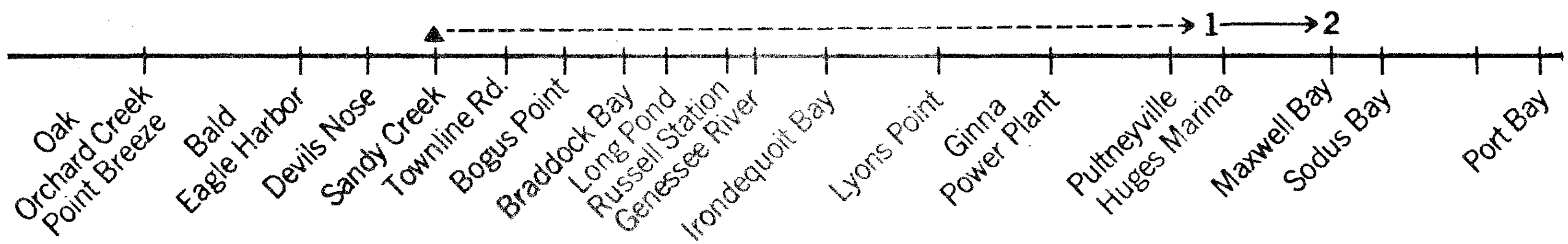
6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

---- Period of Lost Contact

Radio #: 650



Location	Dates
▲	4/18/81 ⟶ 4/20/81
1	4/26/81
2	4/30/81 ⟶ 7/14/81

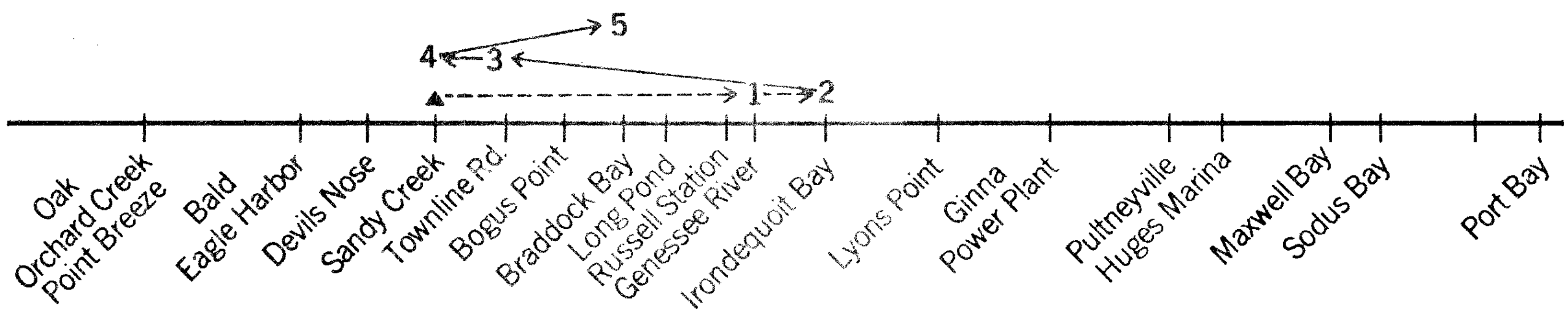
Radio #: 720

|—| 6.2 Kilometers

▲ Location of Capture, Tagging, Release

—— Daily Movements

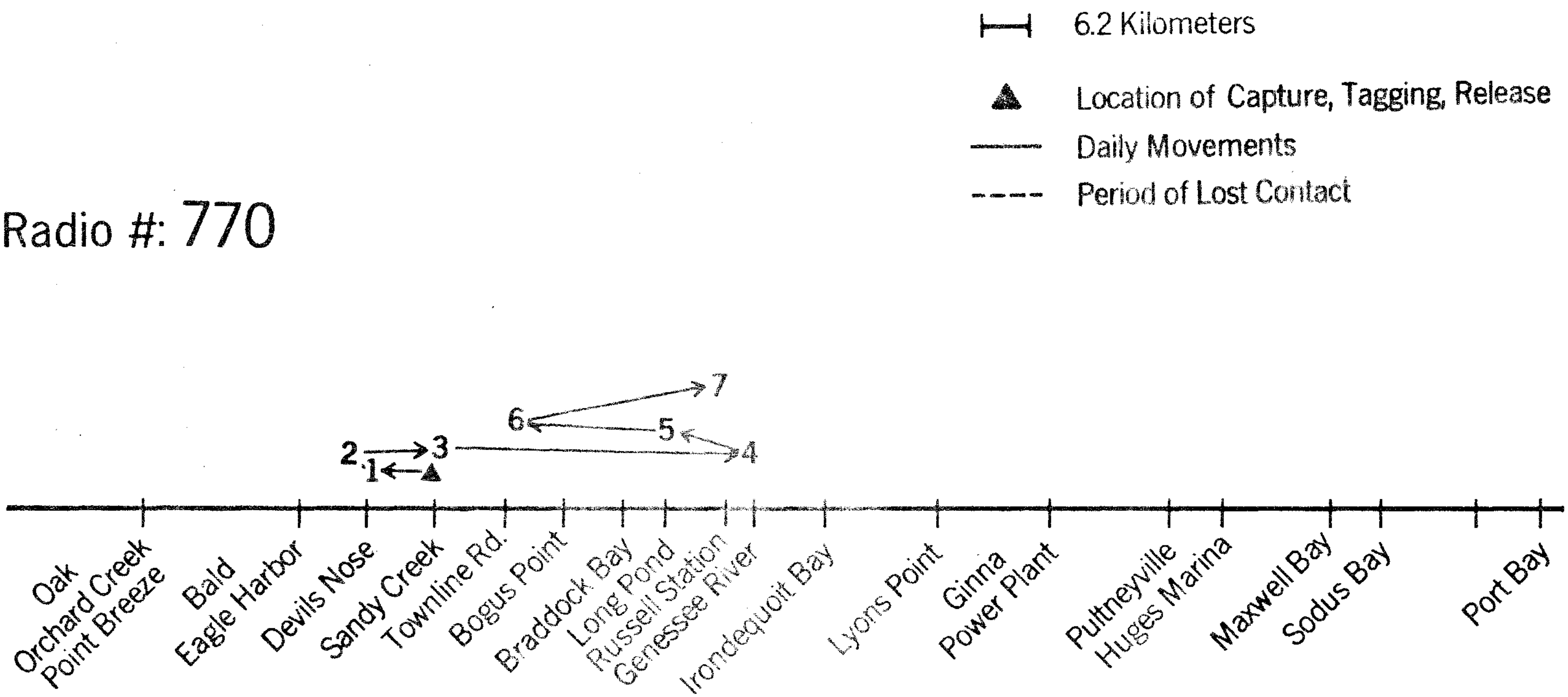
---- Period of Lost Contact



Location	Dates
▲	4/21/81
1	4/25/81 ⟶ 4/26/81
2	5/02/81
3	5/04/81
4	5/05/81 ⟶ 5/06/81
5	5/08/81 ⟶ 6/06/81

Transmitter recovered in Braddock Bay

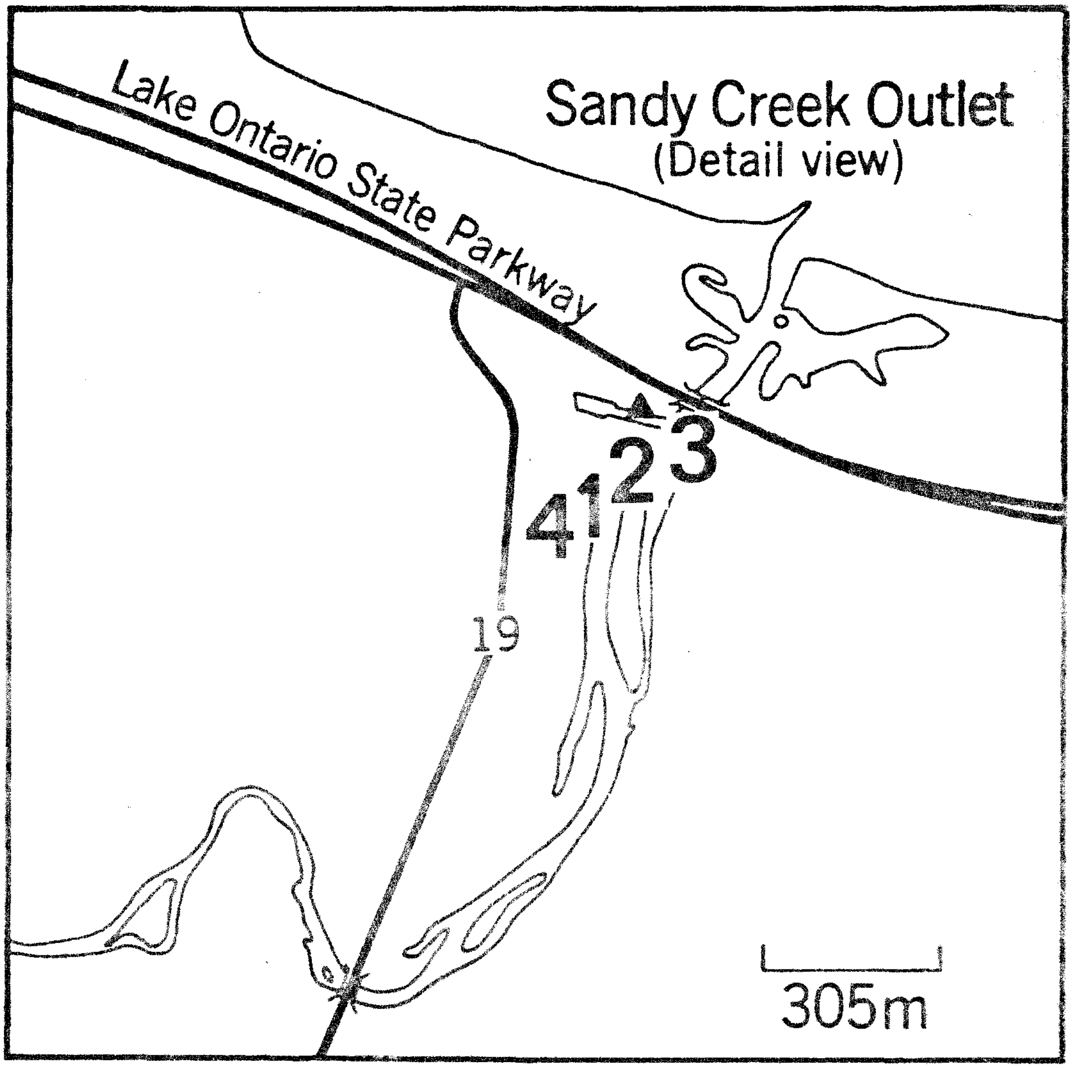
Radio #: 770



Location	Dates
▲	5/03/81
1	5/04/81
2	5/05/81
3	5/06/81
4	5/08/81
5	5/09/81
6	5/10/81
7	5/13/81
	probably died in Round Pond

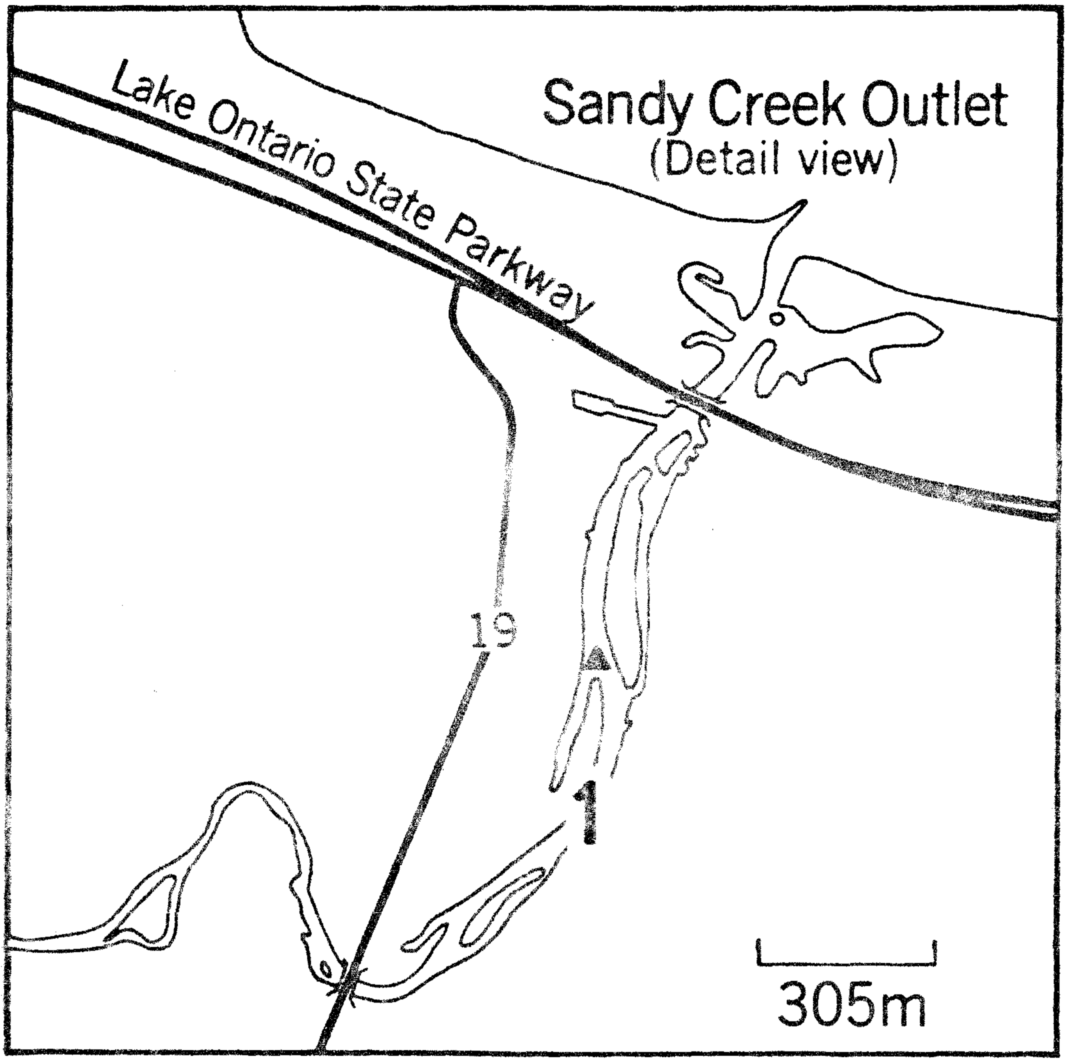
Appendix 3. Fall radio-tagged brown trout creek movements.

Radio #: 280



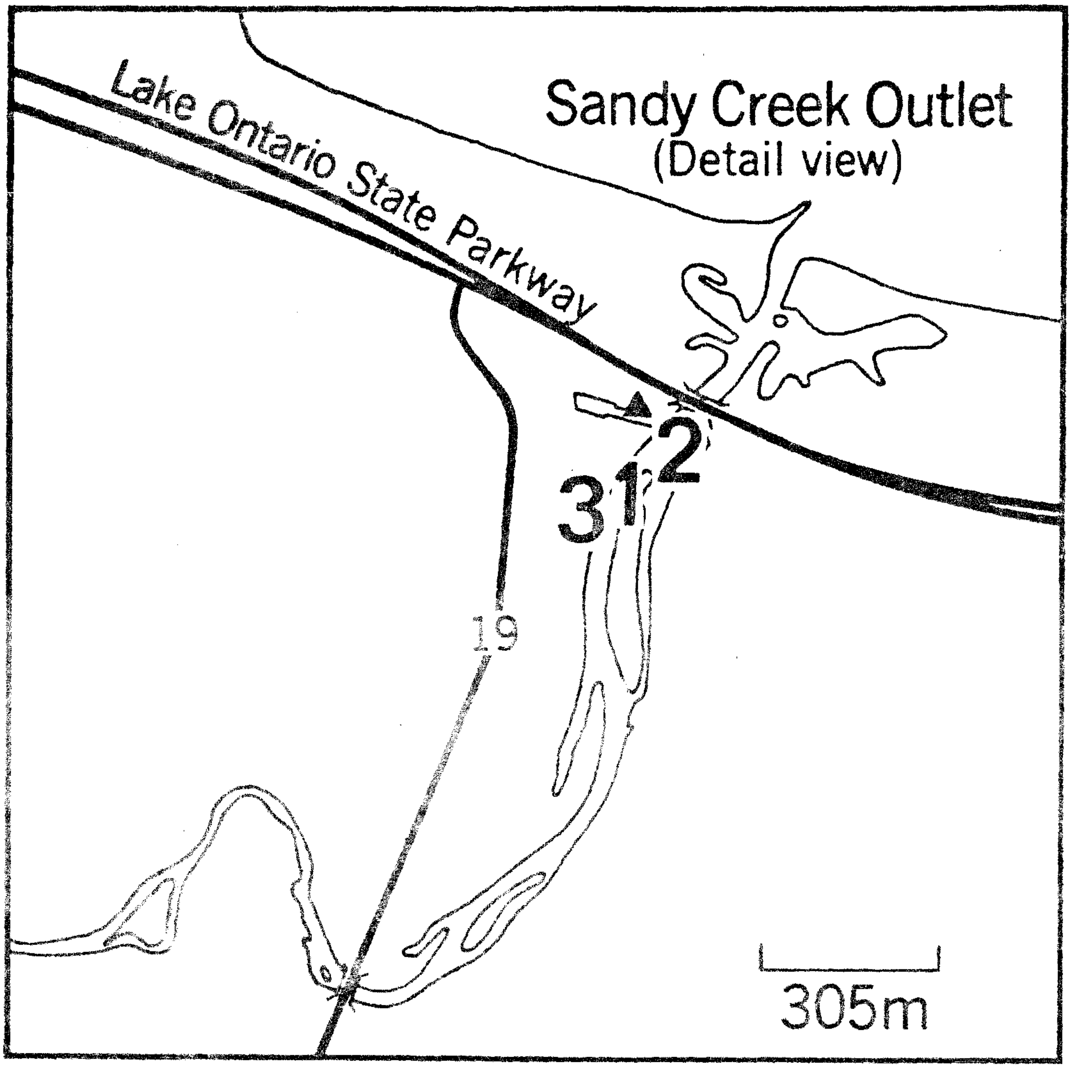
Location:	Date:
▲	9/28/81
1	9/29/81
2	9/30/81
3	9/30→10/4/81
4	10/5/81

Radio #: 290



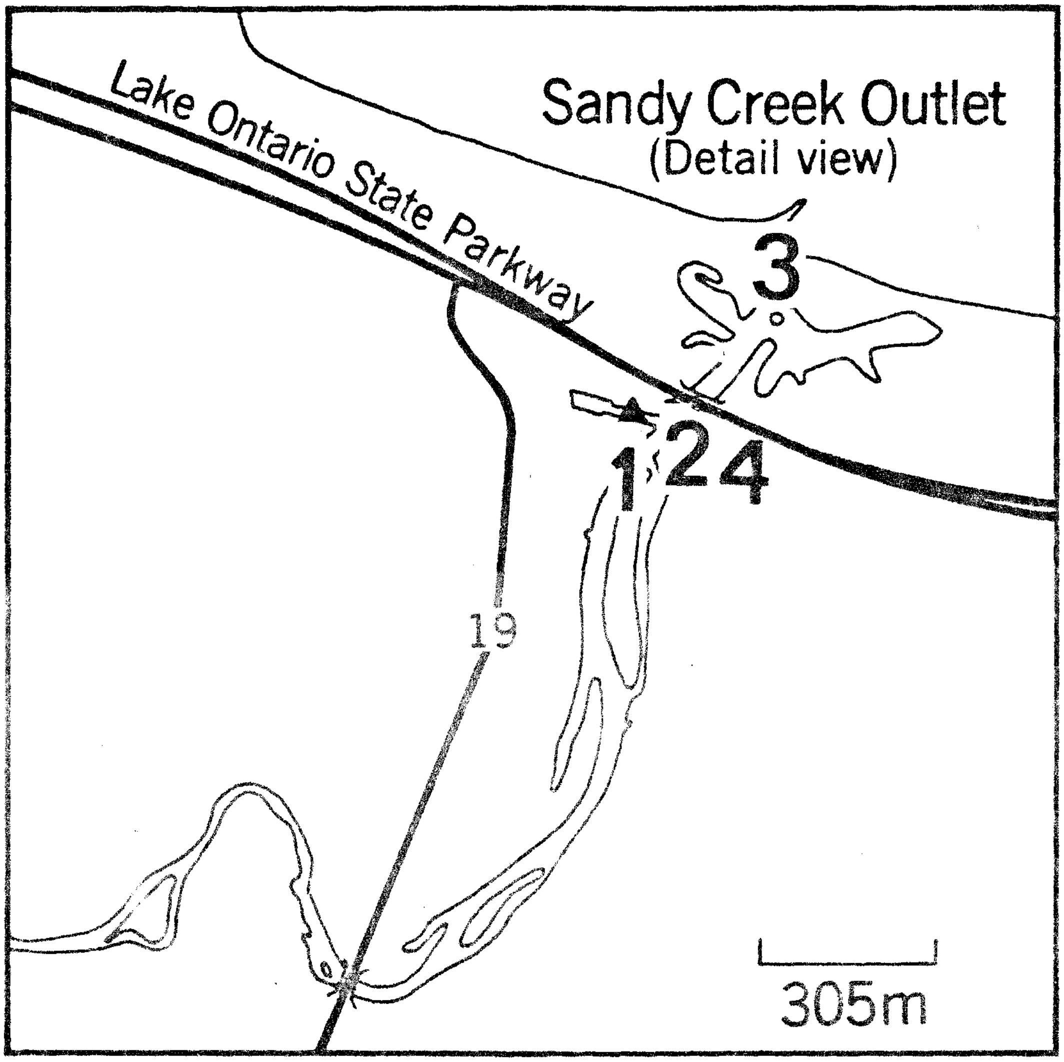
Location:	Date:
▲	11/8/80
1	11/9/80

Radio #: 320B



Location:	Date:
▲	9/22/81
1	9/24/81
2	9/28/81
3	9/29/81

Radio #: 340**B**



Location:	Date:
▲	9/24→29/81
1	9/30→10/4/81
2	10/5→25/81
3	10/26/81
4	10/27→11/12/81