A Food Web Analysis of the Fishery in Chequamegon Bay, Lake Superior

Jennifer A. Devine
University of Wisconsin – Stevens Point
College of Natural Resources
800 Reserve Street, Stevens Point, WI 54481, USA

Stephen T. Schram
Wisconsin Department of Natural Resources
Lake Superior Office
141 South 3rd Street, P.O. Box 589, Bayfield, WI 54814, USA

Michael J. Hansen
University of Wisconsin – Stevens Point
College of Natural Resources
800 Reserve Street, Stevens Point, WI 54481, USA

Abstract.—Prey consumption by coolwater and coldwater predators in Chequamegon Bay, Lake Superior, was modeled to quantify the effect of predators on the fish community and to evaluate current fishery management actions. Coolwater predators included walleye *Sander vitreum*, northern pike *Esox lucius*, and smallmouth bass *Micropterus dolomieu*. Coldwater predators included lake trout *Salvelinus namaycush*, splake *S. fontinalis* × *S. namaycush*, burbot *Lota lota*, lake whitefish *Coregonus clupeaformis*, and brown trout *Salmo trutta*. Predator species diets overlapped and changed annually, depending on prey availability. Rainbow smelt *Osmerus mordax* was the predominant prey of walleye, splake, lake whitefish, and lake trout. Other fish species, such as ninespine stickleback *Pungitius pungitius*, sculpins, shiners and trout perch *Percopsis omiscomaycus*, were the predominant prey of northern pike, smallmouth bass, burbot and splake. Walleye consumed 10.3 million pounds of prey, which was 75% of the total prey consumption. Coolwater predators consumed 80% of total prey consumption, and coldwater predators, which were only present seasonally, consumed 20%. Simulated management actions resulted in small changes in predator consumption; prey consumption was reduced by only 9.1% by changing minimum length limits for smallmouth bass and walleye, and eliminating stocking of walleye, brown trout and splake within Chequamegon Bay. Annual prey fish biomass greatly exceeded annual predator consumption, which suggests that prey may not be limiting predator growth and abundance in Chequamegon Bay.

Chequamegon Bay supports a diverse fish community that is of great economic importance to surrounding communities. The highly productive recreational fishery includes both cool and cold-water species, so differs greatly from the rest of Lake Superior. The once stable fish community became unbalanced between the 1940s and 1960s due to invasions by sea lamprey *Petromyzon marinus* and rainbow smelt *Osmerus mordax*, declines of lake trout *Salvelinus namaycush* and lake herring *Coregonus artedii*, and overexploitation of walleye *Sander vitreum* (Lawrie and Rahrer 1972; MacCallum and Selgeby 1987).

Since then, fisheries management has focused on rehabilitating the native fish community by enacting conservative regulations and stocking walleye. Anglers requested conservative fishing regulations to preserve the size structure of major predators, so regulations were developed for walleye, northern pike *Esox lucis* and smallmouth bass *Micropterus dolomieu*. In addition, the Wisconsin Department of Natural Resources (WDNR) sought to enhance fishing opportunities by stocking brown trout *Salmo trutta*, splake *Salvelinus fontinalis* ´ *S. namaycush*, and Chinook salmon *Oncorhynchus tshawytscha* in the bay, while the Bad River Natural Resources Department stocked walleye into the Kakagon River. In addition to the recreational fishery, a small tribal commercial (gillnetting) fishery for walleye is restricted to the Kakagon River and Kakagon Sloughs.

The WDNR became concerned about the balance between predators and prey in the fish community after predator populations responded to regulations and stocking. A cooperative project using bioenergetics modeling was initiated with the University of Wisconsin – Stevens Point to determine if the fish community within Chequamegon Bay was balanced. Bioenergetics modeling has been used to answer management and research questions concerning predator-prey dynamics and predator consumption, often where stocked fish are important members of the fish community (Ney 1990; Hansen et al. 1993). For example, results of bioenergetics modeling suggested that predator consumption in Lake Superior exceeded prey biomass (Ebener 1995; Negus 1995). In addition, bioenergetics models can be used to predict the effect of increased harvest of predators on prey availability (Hartman and Margraf 1992; Ebener 1995; Negus 1995), examine the efficiency of top-down control of undesirable species (Mayo et al. 1998), describe variation in growth of individual species (Madenjian and Carpenter 1991), and evaluate the roles of predation and competition in structuring fish communities (Stewart et al. 1981).

Our goal was to determine if the abundance of prey fish could adequately sustain predator populations in Chequamegon Bay. Our first objective was to quantify the effect of predators on the Chequamegon Bay fish community using bioenergetics modeling to estimate annual consumption by cool- and coldwater predators. Our second objective was to evaluate the effect of current fishery management actions on food web dynamics by simulating the effect of different management actions on predator consumption. The management actions we simulated included eliminating stocking of brown trout, splake, and walleye in Chequamegon Bay, eliminating the regulation allowing anglers to keep one walleye over twenty inches,

Chequamegon Bay looking southwest. Long Island is at the bottom of the photo

and enacting an 18-inch minimum-length limit on smallmouth bass.

Study Site. - Chequamegon Bay is located on the southwestern shore of Lake Superior (Figure 1). The bay is 19-km long and 8-km wide, has a maximum depth of 23-m, an average depth of 8.6-m, and a surface area of 16,660-ha (Ragotzkie 1969). The south and east side of the bay are less then 5-m deep, but a deep-water channel extends along the western side to provide a cold water refuge for fish species. The bay extends from Houghton Point to the tip of Long Island, a sand barrier that protects and separates the bay from the main body of the lake, though strong winds from the northeast and southwest activate thermal currents between the bay and lake (Ragotzkie 1969; Hoff and Bronte 1999). The bay stratifies thermally from June to September, with surface waters warming to as high as 23ºC in summer, and stratification begins much earlier in the bay than in the rest of the lake (Ragotzkie 1966; Ragotzkie 1969). Lake Superior is highly oligotrophic, so biomass production is low (Lawrie 1978), but embayments are typically more mesotrophic than the lake (Ragotzkie 1969). Five to ten percent of the volume of Chequamegon Bay is flushed daily (Ragotzkie 1969).

Bioenergetics. - Bioenergetics is a balanced energy equation in which the energy of consumed food is partitioned into growth (somatic and gonadal), total metabolism (respiration, active metabolism [swimming speed] and specific dynamic action [food digestion and assimilation]), and waste losses (egestion and excretion). Growth is often easier to estimate in the field than consumption, so bioenergetics can be used to estimate consumption (Hewett and Johnson 1992):

$$\textit{Consumption} = \textit{Growth} - \textit{Total metabolism} - \textit{Waste}$$

Alternatively, by solving the balanced energy equation for growth, bioenergetics modeling can be used to evaluate the effects of limiting factors, such as temperature and prey availability, on growth (Kitchell et al. 1977; Rice et al. 1983):

$$\textit{Growth} = \textit{Consumption} - \textit{Total metabolism} - \textit{Waste}$$

Bioenergetic models are used to describe the energy budget for an average fish in the population, which is then expanded to the entire population by multiplying single-fish dynamics with estimates of cohort survival and population size (Kitchell et al. 1977; Hansen et al. 1993). The bioenergetics model estimates consumption for a group, or cohort, of similarly sized (aged) fish of the same species experiencing identical environmental conditions (Hanson et al. 1997). While individual fish may vary slightly, estimates represent the average individual. To estimate consumption of a cohort, the bioenergetics model requires data on diet composition, energy density of prey and predator, predator physiological parameters, thermal history of the fish, size or age at sexual maturity, and annual endpoints of growth. The net predatory effect of a population can then be predicted by combining cohorts, which requires estimates of predator mortality rates and abundance. Estimates of prey biomass are necessary to compare predicted consumption with available prey.

Fish Sampling. - Predators were captured during 1998-2001 using gillnets, fyke nets, trap nets, seining and angling. Gillnets were set for 1-2 hours to sample cool- and

Fish were captured and released alive from an eight foot trap net.

coldwater species at sites that were selected based on habitat, including shoals, drop-offs, weed beds, areas with structure, and random sites along the deep-water channel. Gillnets were 30.5-meters long with mesh sizes ranging

Pumping a lake trout stomach. Notice the diet items on the screen.

Table 1. Weight-length relationships (total length) for prey species in Chequamegon Bay, Lake Superior, 2001.

Scientific Name	Common Name	Intercept	Slope
Coregonus clupeaformis	Lake Whitefish[a]	–5.57	3.19
Gymnocephalus cernuus	Ruffe[a]	–4.43	2.79
Perca flavescens	Yellow perch[a]	–5.08	3.08
Alosa pseudoharengus	Alewife[b]	–3.77	2.51
Ictalurus nebulosis	Brown Bullhead[b]	–5.06	3.07
Luxilus cornutus	Common Shiner[b]	–5.56	3.29
Notropis atherinoides	Emerald Shiner[b]	–4.71	2.73
Catostomus catostomus	Longnose Sucker[b]	–5.07	3.02
Lepomis gibbosus	Pumpkinseed[b]	–4.77	2.97
Prosopium cylindraceum	Round Whitefish[b]	–5.27	3.22
Cottus ricei	Spoonhead Sculpin[b]	–5.28	3.17
Percopsis omiscomaycus	Trout-Perch[b]	–5.03	3.08
Catostomus commersoni	White sucker[b]	–5.05	3.04
Osmerus mordax	Smelt[c]	–5.55	3.12
Ameiurus melas	Black Bullhead[#d]	–10.81	2.92
Etheostoma nigrum	Johnny Darter[#d]	–12.92	3.20
Percina caprodes	Log Perch[#d]	–11.90	3.05
Pungitius pungitius	Ninespine Stickleback[e]	–5.30	3.08
Coregonus artedii	Lake Herring[e]	–5.18	3.01
Cottus cognatus	Slimy Sculpin[f]	–5.49	3.32

Note: Relationships are $\log_{10}$ unless noted with a #, then relationships are $\log_e$. [a] This study; [b] Carlander (1977) [c] USGS (unpublished data); [d] Becker (1983); [e] WDNR (unpublished data); [f] Selgeby (1988)

from 38-mm to 133-mm stretched-mesh in 13-mm increments, 210/2 monofilament, and hung on the ½ basis. Depths sampled ranged from 1.5-meters to 17.5-meters. During 1998 and 2000, a graded-mesh survey was also conducted using nets with meshes ranging from 25-mm to 178-mm stretched-mesh in 13-mm increments, 210/2 monofilament, hung on the ½ basis, and fished at four fixed locations for 24 hours. Locations spanned the deep-water channel (4.5-21 meters). Predators were collected along the Ashland shoreline using 1.2-meter fyke nets with 10-mm or 25-mm stretch mesh, and 23-meter leads. Fyke nets were lifted every 24 hours. A single-pot trap net consisting of 51-mm stretch mesh in the wings and heart and 25-mm stretch mesh in the pot was fished in water 3-8 meters deep along the Ashland shoreline and on shoals. The trap net had a 61-meter lead of 51-mm stretch mesh, but was also used with a 23-meter lead of 25-mm stretch mesh for a total of 84 meters. A 15-meter bag seine with 5-mm mesh was used in Kakagon and Sandcut sloughs, near Fish Creek, and along the Ashland shoreline. A single 30-meter pull was made at each site along the shoreline. Angling samples were collected throughout the bay during the year.

*Diet Sampling.*¾Stomach contents were removed by pumping water into the stomach using a nozzle, hose and small bilge pump. Stomach samples were either processed immediately or contents were frozen and processed within several months of collection. Prey species were identified to the lowest practical taxon, usually species for fish and family for invertebrates, and wet weight of stomach contents was measured to the nearest 0.1 gram. All fish prey were measured to the nearest 0.1-inch (total, standard or backbone length, as practical). Length was converted from SL to TL using conversion factors from Carlander (1977), Becker (1983), or approximated using conversion factors for species in the same family. Weights of all fish prey species were estimated from species-specific weight-length equations, or approximated using species in the same family (Table 1).

Prey items were divided into eight categories, including rainbow smelt, yellow perch *Perca flavescens*, coregonines, salmonines, other fish, crayfish, other crustaceans (*Diporeia, Mysis* and *Bythotrephes*), and other invertebrates, and expressed as percentage of diet by weight for each predator age class. Unknown fish were distributed according to the proportion of identified fish in a predator's diet. Because of the lack of adequate diet data over time and across age classes, diet samples were grouped if predators did not show a diet shift with age. For young age classes not sampled, diet information was taken from the literature. Diet was broken down by simulation day for each age group, with day 1 set to June 1st because most naturally produced

Table 2. Energy density of eight prey categories used in bioenergetics modeling of Chequamegon Bay, Lake Superior, 2001. Crustaceans include only *Mysis, Diporeia* and *Bythotrephes*. Energy density is in joules per gram wet weight.

Prey Species	Day	Energy Density	Source
Smelt	June 1	4,054.5	Lantry and Stewart (1993)
	July 1	4,157.5	
	July 31	4,600.5	
	Sept. 1	4,186	
	Sept. 30	4,012	
	Feb. 28	4,005.5	
	May 31	4,054.5	
Yellow Perch		5,700	Hartman and Margraf (1992)
Coregonines		7,500	Ebener (1995)
Salmonines		5,441	Negus (1995)
Other fish		4,679	Mayo (1997), Hartman and Margraf (1992)
Crustaceans		4,310	Stewart et al. (1983)
Crayfish		3,200	Yako et al. (2000)
Other Invertebrates		3,200	Ebener (1995), Negus (1995)

Figure 1. Depth contour map of Chequamegon Bay, Lake Superior with major towns and spawning areas (redrawn from Fishing Hot Spots, Inc.). Locations of temperature loggers are noted by filled in circles. Depths are in feet.

predators would have hatched by that date. Changes in diet were estimated by linear interpolation between simulation dates within the bioenergetics program.

Energy Density. - Prey caloric density was obtained from the literature (Table 2). For other fish species, energy density was estimated as an average of energy densities for predominant species in the category (ninespine stickleback *Pungitius pungitius*, trout-perch *Percopsis omiscomaycus*, slimy sculpin *Cottus cognatus*, emerald shiner *Notropis atherinoides*, and spottail shiner *Notropis hudsonius*). Rainbow smelt undergo an ontogenetic change in energy density (Lantry and Stewart 1993). Because predators fed on rainbow smelt of all sizes, an average of adult and juvenile rainbow smelt energy density was used. Most predator caloric density estimates were included in the internal parameters of the bioenergetics model, but burbot *Lota lota* energy density was taken from Johnson et al. (1999). Energy density of splake and brown trout were borrowed from lake trout (Hanson et al. 1997).

Physiological Parameters. - Predator physiological parameters for consumption, respiration, and egestion-excretion were taken from Hanson et al. (1997) for all species except burbot, lake whitefish *Coregonus clupeaformis*, and smallmouth bass. Burbot physiological parameters were taken from Rudstam et al. (1995). Activity parameters for lake whitefish were replaced with parameters for the lake trout swimming-speed sub-model, which describes swimming speed as a function of water temperature and fish weight, because the model for coregonines overestimates lake whitefish swimming speed (C. Madenjian, USGS, Ann Arbor, Michigan, personal communication). Smallmouth bass parameters were taken from Whitledge et al. (2003). Lake trout physiological parameters were used to simulate splake and brown trout.

Thermal History. - Temperature was recorded every four hours from early May through the end of November in 2000 with two temperature loggers located at 5 and 9-meters in depth (Figure 1). Temperatures were also taken every two weeks at one-meter depth intervals with a temperature-depth profiler at depths of 5 and 9-meters in the inner bay and at 18-meters in the outer bay from early June through November in 2000. Temperature for missing months (December – April) was estimated from the relationship between temperature and month:

$$Temperature = (a*month) + (b*month^2) + (c*month^3).$$

This equation describes a sine wave, such as that generated by temperature cycles. December temperature was first set at 4°C, and was then estimated using the temperature model.

Weights were collected from all major predators such as this northern pike.

Table 3. Day, age of maturity, and spawning losses incurred for seven predator species in Chequamegon Bay, Lake Superior, 2001. Splake were assumed to have no natural reproduction.

Species	Day	Age	Spawning loss	Source
Lake trout	October 30	9	6.8%	Stewart et al. (1983)
Brown trout	October 16	3	18%	Hayes et al. (2000)
Lake whitefish	November 9	6	10%	Rudstam et al. (1994)
Burbot	February 13	3	11%	Rudstam et al. (1995)
Smallmouth bass	June 1	5	11%	WDNR unpublished data
Walleye	April 25	6	10%	Schram et al. (1992)
Northern pike	April 25	4	13%	Diana and Mackay (1979)

The depth at which a species was most frequently captured was used to model the temperature preference of each predator species. Lake trout, lake whitefish and burbot of ages 3 and older were modeled with temperatures at 18 meters. Brown trout, splake and burbot of ages 1 and 2 were modeled with temperatures at 9 meters. Northern pike *Esox lucius* were modeled with temperatures at 5 meters. Walleye were modeled with temperatures at 4 meters for June through October, 9 meters for December, and 5 meters for remaining months. Smallmouth bass of ages 1 and 2 were modeled with temperatures at 2 meters for May through October, 5 meters for November, and 4 meters for remaining months. Smallmouth bass of ages 3 and older were modeled using temperatures at 4 meters for May and June, 9 meters for August and September, and 5 meters for remaining months.

Maturity. - Reproductive losses through spawning were simulated at an age or size when most of the population was estimated to be sexually mature. Spawning losses were an average of male and female percentage of body weight lost. Age at maturity and spawning losses were taken from the literature for each species (Table 3).

Growth. - Length was measured on all predators, weight was measured whenever possible, and bony structures were collected for age estimation (Devries and Frie 1996). Weight-length relationships were estimated for all species using linear regression on $\log_{10}$-transformed weight and length data:

$$\log_{10}(W_t) = \log_{10}(\alpha) + \beta \log_{10}(L_t) + \varepsilon_t ;$$

$$\log_{10} M = -0.0066 - 0.279 \log_{10}(L_\infty) + 0.6543 \log_{10}(K) + 0.4634 \log_{10}(T)$$

where W_t = weight, L_t = length, α = intercept, and b = slope.

Parameters of the von Bertalanffy growth model were estimated numerically for length and weight of individual fish:

$$\log_e(L_i) = \log_e\left(L_\infty\left(1 - \exp^{-K(t_i - t_0)}\right)\right) + \varepsilon_i ;$$

where L_i = length, L_∞ = average asymptotic length for the population, K = rate at which L_i approaches L_∞, t_i = age, and t_0 = hypothetical age at zero length, and

$$\log_e(W_i) = \log_e\left(W_\infty\left(1 - \exp^{-K(t_i - t_0)}\right)^\beta\right) + \varepsilon_i ;$$

where b is estimated from the weight-length relationship and the other parameters are the same as those in the length-age model. Parameters from the length-age model were used to estimate annual endpoints of growth when the weight-age model would not converge. Otherwise, the weight-age model was used to estimate annual endpoints of growth for each predator age class.

Mortality.¾Total instantaneous mortality was estimated from age frequencies for each species. For all predators except smallmouth bass and burbot, age frequencies were estimated by multiplying estimated predator abundance times predator catch frequency. Mortality for smallmouth bass was estimated by following the 1987 year-class from 1991 through 1999. To estimate burbot mortality, the age frequency was estimated by applying a catch frequency of burbot captured in 1997 and 1999 in Lake Superior during WDNR summer surveying to the estimated burbot abundance in Chequamegon Bay (see below).

Instantaneous total mortality (Z) was estimated using linear regression of $\log_e$-transformed catch against age:

$$\log_e(N_t) = \log_e(N_0) - Zt + \varepsilon ;$$

where N_t is numbers at age t, and N_0 is number at age 0. Total annual mortality (A) was then estimated from the equation:

$$A = 1 - \exp^{-Z} .$$

For smallmouth bass, instantaneous fishing mortality was estimated from exploitation rates using the equation:

$$F = u\left(Z/A\right);$$

Northern pike were captured by fyke net at Sand Cut.

where Z = total instantaneous mortality (estimated from catch curve), A = total annual mortality, and u = average exploitation

$$\left(R/M\right),$$

where R = number of recaptures in recreational and WDNR fisheries surveys and M = number of marked fish from mark-recapture studies (see below).
For other predator species except lake trout, instantaneous fishing mortality was estimated by difference:

$$F = Z - M ;$$

where M = instantaneous natural mortality rate, estimated from Pauly's equation:

;

where L_∞ and K are parameters from the von Bertalanffy growth model and T is average water temperature in Celsius measured in Chequamegon Bay. Lake trout natural and fishing mortality rates were borrowed from Linton (2002). Instantaneous fishing and natural mortality rates were converted into conditional rates for all species for use in the bioenergetics model.

Smallmouth bass were sampled by electrofishing at Sand Cut.

For all predators except lake trout, instantaneous fishing mortality rates for ages not fully vulnerable to the fishery were estimated by the equation:

$$F_x = s_x F \;;$$

where F_x is instantaneous fishing mortality of fish age x not fully vulnerable to the fishery, s_x is the proportion of each age class fully vulnerable to the fishery [ranging from 0 (not vulnerable) to 1 (fully vulnerable)], and F is fishing mortality. For lake trout, instantaneous fishing mortality rates were borrowed from Linton (2002).

*Predator Abundance.*¾Abundance (N) of mature northern pike was estimated by mark-recapture in 2001 using the Chapman modification of the Peterson estimator:

$$N = \frac{(M+1)*(C+1)}{R+1} - 1 \;;$$

where M = number of fish marked, C = number of fish examined for marks, and R = number of fish recaptured.

Northern pike spawning areas were sampled with fyke nets at Short Bridge, Washburn, Sandcut, and Kakagon sloughs (Figure 1). Each area was sampled 15-19 net-nights, except Sandcut, which was sampled 40 net nights. Northern pike were collected using 1.2-meter fyke nets with 10-mm or 25-mm stretch mesh and 23-meter leads. Nets were lifted every 24 hours. Fish were marked by partial removal of a fin. Fish from different spawning areas were marked with different fin clips. Northern pike were recaptured in August using one hour gillnet sets (described above).

Abundance of mature smallmouth bass was estimated by mark-recapture in spring 2001 during spawning in Sandcut and Kakagon Sloughs using the Chapman modification of the Peterson estimator. Smallmouth bass in Sandcut were captured using three 6-meter AC electrofishing boats equipped with a 230-volt 3-phase generator operated at 80% duty cycle at 2-4 amperes, and two people dipping in each boat. Smallmouth bass were marked by clipping the top lobe of the caudal fin on the first night of sampling, and were recaptured the following night. The entire area of Sandcut was not sampled because some areas were too shallow for the boats, while others were too deep for the current to be effective. Smallmouth bass in Kakagon Sloughs were captured by hook and line. Smallmouth bass were marked over five consecutive days by clipping the bottom lobe of the caudal fin. Smallmouth bass were recaptured in August of 2001 using one hour gillnet sets (described above).

Abundance of the Kakagon Slough spawning walleye population was estimated in 1998 by the U.S. Fish and Wildlife Service and the Bad River Natural Resources Department using the Chapman modification of the Peterson estimator. Walleye longer than 406-mm were captured in 101-mm to 127-mm stretch mesh monofilament gill nets and marked with an orange Floy tag and caudal fin-hole punch. Walleye were recaptured with fyke nets. To estimate the number of stocked fingerlings surviving to 2001, walleye stocking records (1980-2001) were used with the previously estimated walleye survival rate.

Abundance of self-sustaining coldwater predators was estimated by multiplying the ratio of the average catch of coldwater predator to the average catch of lake trout in summer gillnet surveys during 1998-2001, times the abundance of lake trout estimated in Chequamegon Bay. Abundance of lake trout (N) was estimated from Baranov's catch equation:

$$C = \frac{F}{Z} NA \;;$$

where C is the average catch of lake trout in Chequamegon Bay from creel surveys during 1998-2001 (WDNR unpublished data), F is the average instantaneous fishing mortality of stocked and wild lake trout, Z is the total instantaneous mortality, and A is the total annual mortality. Lake trout mortality rates were taken from Linton (2002). Population estimates were used to generate catch curves from which numbers at age were estimated (see above). Abundance at age of stocked splake in 2001 was estimated by applying the estimated survival rate to the number of fingerlings stocked. Abundance of stocked brown trout at ages 2 and older was estimated by multiplying the estimated abundance of native brown trout by the ratio of the average catch of stocked brown trout to native brown trout in WDNR summer gillnet surveys in 1994, 1998, and 2000.

Abundance at age of all predators not fully vulnerable to the fishery was estimated by the equation:

$$N_t = \log_e N_0 - Zt + \varepsilon \;;$$

where N_t = abundance at age t, $\log_e N_0$ = the intercept from the instantaneous total mortality estimate of the population, and Z = instantaneous total mortality rate. Abundance at age for younger fish was found by back calculating from ages used to estimate total instantaneous mortality, while abundance of fish older than those used to estimate mortality was estimated by forward casting.

Prey Abundance. - Prey species populations were surveyed in the bay each year during 1995-1998 with bottom trawls (for details see Buckner 1995, Hoff and Bronte 1999).

Weights for prey species were estimated from weight-length relationships (Table 1). Biomass per hectare was estimated by multiplying summed weights of each species in each year by the area swept by trawls. Biomass per hectare was then multiplied by the total area of Chequamegon Bay (16,660-ha) to estimate the total biomass of prey species each year. Average biomass of each species was determined by averaging total biomass during 1995-1999.

Total prey biomass includes the amount of biomass existing at the time of the trawl survey plus the amount of prey produced during the course of the year, so production was

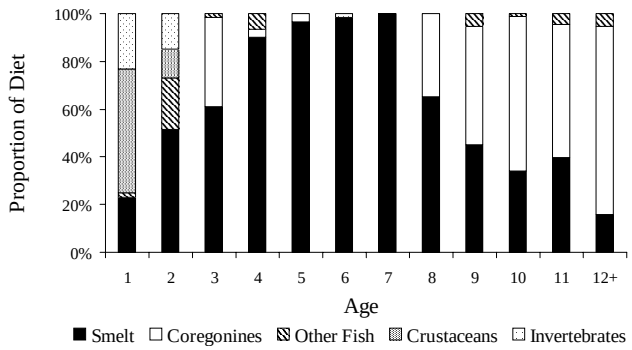

Figure 2. Proportion of diet of lake trout by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

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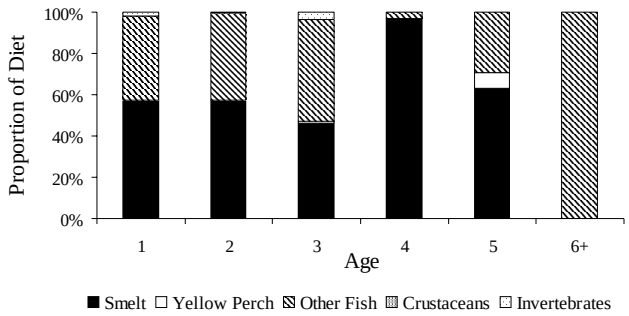

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stickleback and spottail shiner. Rainbow smelt were the predominant prey item during the year for lake trout of ages 3-7, except in June when other species were eaten in higher proportions (Appendix A). Diet of lake trout of age 8 and older varied throughout the year. Older lake trout fed mainly on rainbow smelt and coregonines, except in winter, when other fish species were eaten in higher proportions, and in spring (April-March), when predominant prey were coregonines and other fish species. Lake trout of ages 1 and 2 were not collected, so diets for these ages were taken from Negus (1995).

Figure 3. Proportion of diet of brown trout by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

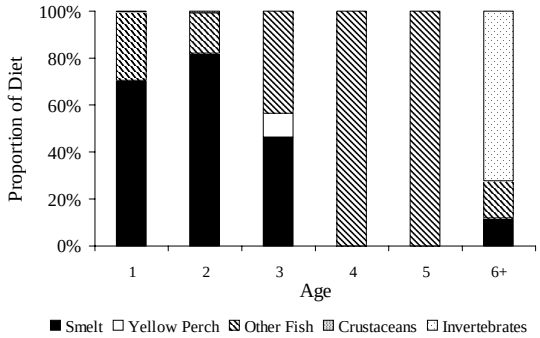

Figure 4. Proportion of diet of splake by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

Brown trout fed predominantly on rainbow smelt and other fish species at all ages (Figure 3). Other fish species eaten included primarily ninespine stickleback and emerald shiner. Diet samples from all ages were combined because few samples were collected over a wide range of dates for all ages. Brown trout fed mainly on rainbow smelt, except in autumn (September-December), when other fish species were predominant prey items (Appendix B).

Splake of ages 1-3 fed mainly on rainbow smelt and other fish species (Figure 4). Other species of fish eaten in high proportions were ninespine stickleback and sculpins. Because of small sample size of splake age 4 and older, diets of all ages were grouped together. Diet of splake did not change annually (Appendix C). Splake fed predominantly on rainbow smelt throughout the year.

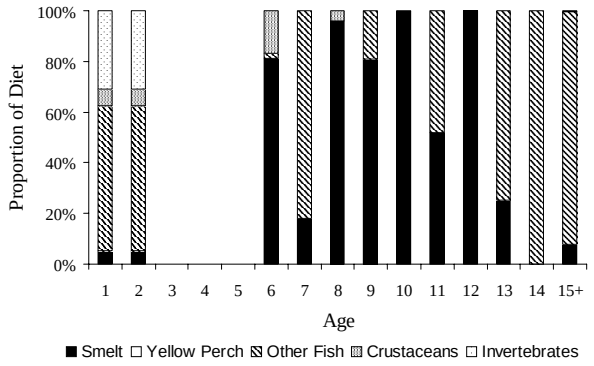

Figure 5. Proportion of diet of burbot by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

Other fish species were eaten in higher proportions during July to early August, whereas yellow perch were eaten in higher proportions in November.

Burbot sample size was small and information on burbot of ages 1-5 was lacking (Figure 5), so diets of burbot of

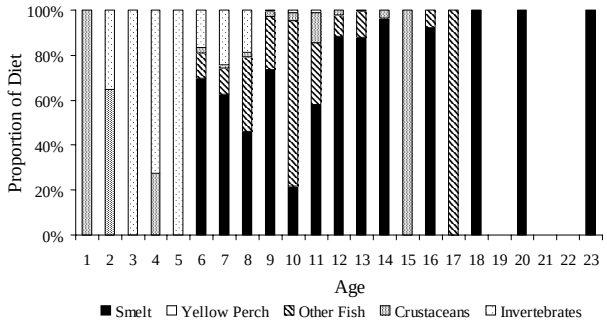

Figure 6. Proportion of diet of lake whitefish by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

ages 1 and 2 were taken from Fratt (1991). Age 6 and older burbot ate primarily rainbow smelt and sculpins. All samples were combined to represent the diet of burbot of age 3 and older. Burbot diet changed seasonally (Appendix D). Coregonines and rainbow smelt were predominant prey during spring and summer (March-July), whereas other fish species and coregonines were predominant prey during the rest of the year.

Lake whitefish of ages 1-5 fed only on amphipods, *Bythotrephes* and other invertebrates, whereas lake whitefish of age 6 and older fed predominantly on rainbow smelt (Figure 6). Other invertebrates and fish species eaten in

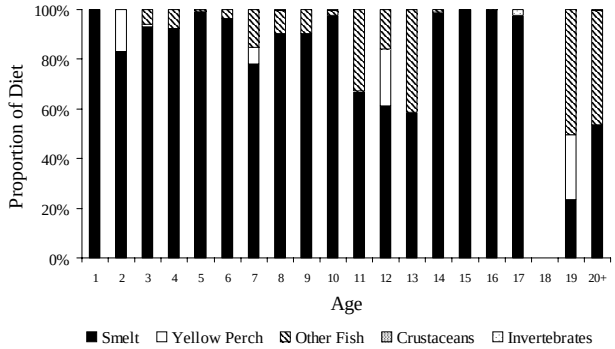

Figure 7. Proportion of diet of walleye by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

high proportions included fingernail clams (Sphaeriidae), spottail shiner, and trout-perch. Lake whitefish diet changed annually (Appendix E). Lake whitefish of ages 1-5 ate amphipods in high proportions during summer and other invertebrates during the rest of the year. Lake whitefish of age 6 and older ate predominantly rainbow smelt throughout the year, and other fish species in higher proportions during September-October and February-March.

Walleye fed predominantly on rainbow smelt at all ages (Figure 7), whereas other fish species eaten in high proportions were ninespine stickleback and shiners. Diet of walleye did not change with age, so diets of all ages of walleyes were combined. Walleye fed predominantly on rainbow smelt throughout the spring and summer, and switched to yellow perch, coregonines, salmonines, and other fish species in autumn and winter (Appendix F).

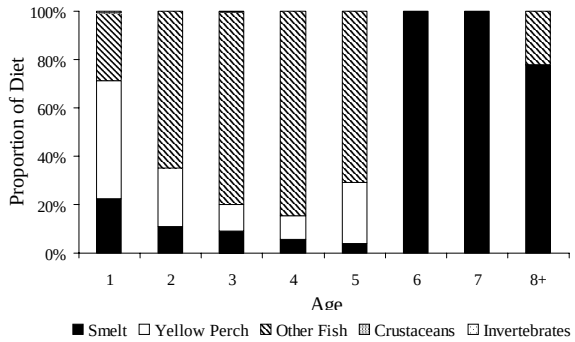

Figure 8. Proportion of diet of northern pike by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

Diets of northern pike changed with age (Figure 8). Age 1-2 northern pike fed mostly on yellow perch, other fish species, and rainbow smelt, whereas age-3 northern pike ate mainly other fish species, and age-4-and-older northern pike ate primarily coregonines, salmonines and rainbow smelt. Other fish species eaten in high proportions by northern pike of all ages were white sucker *Catostomus commersoni*, trout-perch, ruffe *Gymnocephalus cernuus*, and various species of shiners. Northern pike diets changed annually and seasonally (Appendix G). Age 1-2 northern pike ate mostly rainbow smelt in July, yellow perch in September, and other fish species during the rest of the year. Age-3 northern pike fed mainly on coregonines in early summer, rainbow smelt during summer (July through mid-September), and other species of fish during the rest of the year. Age-4-and-older northern pike fed mainly

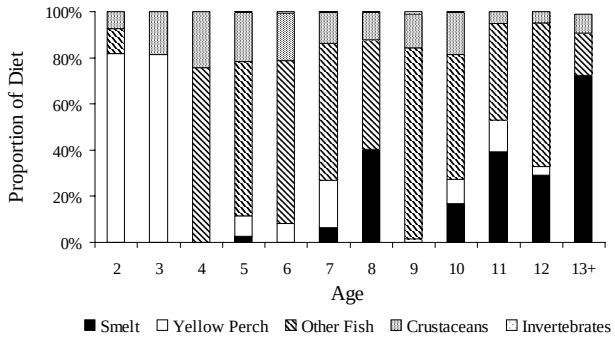

Figure 9. Proportion of diet of smallmouth bass by age in Chequamegon Bay, Lake Superior, 1998–2001. Other fish includes salmonines, coregonines and smal species of fish.

Lead author with a sample of smallmouth bass.

Table 4. Average temperatures recorded at five depth stations from May through November and estimated for December through April in Chequamegon Bay, Lake Superior, 2000. Temperature is in degrees Celsius.

	Depth (meters)				
Day	4	2	5	9	18
June 1	10.3	10.6	11.3	9.4	7.5
June 30	12.8	13.4	11.9	10.7	8.2
July	16.9	17.3	16.0	13.9	10.8
August	20.1	20.5	17.9	15.0	9.8
September	14.9	14.9	14.8	14.1	8.4
October	12.6	12.5	11.3	10.8	10.5
November	2.6	2.6	5.0	5.1	3.7
December	1.5		1.9	2.4	2.1
January	1.1		1.5	1.0	
February	3.2		3.6	2.8	1.8
March	5.9		6.2	5.0	3.8
April	8.9		8.8	7.4	6.1
May	10.3		10.8	9.4	6.2

on salmonines in early summer and other fish species during the rest of the year. Rainbow smelt were eaten infrequently, but were the predominant prey when eaten.

Smallmouth bass of ages 1-9 fed mainly on yellow perch and other fish species, while smallmouth bass of age 10 and older fed mainly on rainbow smelt and other fish species (Figure 9). Smallmouth bass of ages 1-9 ate a higher proportion of crayfish than older bass. Smallmouth bass of all ages fed on similar species of other fish; however, smallmouth bass of ages 1-9 fed on more sculpins than older age classes. Diet of all age groups did not change seasonally, other fish species were the predominant prey throughout the year (Appendix H).

Thermal History

Temperatures at all sites except the deepest site (18-meters) were highest in August and lowest in January (Table 4). Temperature at the deepest site was highest in July and October, and lowest in February, and temperature in October was similar to temperatures at other stations. The temperature estimated for January at the deepest site was not used because the estimated temperature was too low (0.76 degrees C), so temperature was allowed to decrease linearly from December to February.

Predator Growth

Growth varied greatly among predator species. Northern pike, brown trout and lake trout reached the largest asymptotic lengths and weights (Table 5). Asymptotic

Table 5. Sample size (N), coefficient of determination (R2), and parameters for weight-length relationships and von Bertanffy length-age and weight-age models for predator species in Chequamegon Bay, Lake Superior, 1998-2001. Parameters K and t_0 from the length-age models for northern pike, brown trout and burbot were used to solve for W_∞ because the weight at age models for these species would not converge. Lake trout parameters are from Linton (2002).

	Species							
Parameter	Walleye	N Pike	SM Bass	Lake Trout	Brown Trout	Splake	L Whitefish	Burbot
Weight-length relationship:								
N	307	469	315	8301	64	110	146	366
R^2	0.96	0.94	0.98	0.92	0.91	0.88	0.99	0.91
β	3.17	3.44	2.97	2.997	2.97	3.16	3.19	3.11
α	-5.46	-6.42	-4.72	-5.04	-4.87	-5.44	-5.57	-5.40
Length-age model:								
N	1262	450	1034	273	36	104	169	304
R^2	0.82	0.69	0.91	0.93	0.68	.68	0.86	0.58
L_∞ (mm)	702.86	1035.04	473.23	833.10	882.62	642.54	737.86	657.50
K	0.14	0.16	0.18	0.15	0.19	0.37	0.13	0.18
t_0	-1.85	-1.75	0.04	-0.45	-1.39	-0.96	-0.81	-0.27
Weight-age model:								
N	155		1034	6207			62	121
R^2	0.69		0.85	0.53			0.62	0.82
W_∞ (g)	3072.17	8588.50	1935.02	5335.20	7692.68	1870.37	3358.67	2322.84
K	0.16		0.207	0.12			0.605	0.18
t_0	-2.49		-1.04	-2.45			-0.27	0.42

Table 6. Total instantaneous mortality (Z), conditional fishing mortality (Fm), and conditional natural mortality (Mn) rates for predators in Chequamegon Bay, Lake Superior, in 2001. Mortality rates for lake trout of ages 4 and older were taken from Linton (2002); Fm and Z is the average for wild and stocked lake trout during 1980-2000. To simulate elimination of the 20-inch minimum length limit on walleye, fishing and natural mortality from age 9 was used. To simulate the effect of an 18-inch minimum length limit on smallmouth bass, conditional fishing mortality was set at 0.0268 for age 9, 0.0674 for age 10, 0.0912 for age 11, 0.1144 for age 12, 0.1628 for age 13, and 0.2168 for age 14+.

	L Whitefish		Walleye		SM Bass		Burbot		NPike		L Trout		Splake		B Trout	
Z	0.28		0.67		0.43		0.55		0.89		0.44		1.22		0.51	
Age	Fm	Mn	Fm	Mn	Fm	Mn	Fm	Mn	Fm	Mn	Fm	Mn	Fm	Mn	Fm	Mn
1	0	0.24	0	0.49	0	0.35	0	0.42	0	0.59	0.56	0	0.16	0.65	0	0.40
2	0	0.24	0	0.49	0	0.35	0	0.42	0	0.59	0.56	0	0.52	0.38	0.16	0.29
3	0	0.24	0	0.49	0	0.35	0	0.42	0	0.59	0.56	0	0.56	0.36	0.23	0.22
4	0	0.24	0.13	0.41	0	0.35	0	0.42	0	0.54	0.02	0.17	0.55	0.35	0.23	0.22
5	0.03	0.22	0.24	0.32	0	0.35	0	0.42	0.25	0.46	0.12	0.17	0.55	0.35	0.23	0.22
6	0.06	0.20	0.25	0.32	0	0.35	0	0.42	0.36	0.36	0.14	0.17	0.55	0.35	0.23	0.22
7	0.08	0.18	0.33	0.24	0	0.35	0	0.42	0.43	0.28	0.15	0.17	0.55	0.35	0.23	0.22
8	0.09	0.16	0.33	0.23	0	0.35	0	0.42	0.45	0.25	0.15	0.17	0.55	0.35	0.23	0.22
9	0.09	0.16	0.35	0.20	0	0.35	0	0.42	0.49	0.20	0.14	0.17	0.55	0.35	0.23	0.22
10	0.09	0.16	0.35	0.20	0	0.35	0	0.42	0.49	0.20	0.14	0.17	0.55	0.35	0.23	0.22
11	0.09	0.16	0.35	0.20	0	0.35	0	0.42	0.49	0.20	0.14	0.17	0.55	0.35	0.23	0.22
12	0.09	0.16	0.35	0.20	0	0.35	0	0.42	0.49	0.20	0.13	0.17			0.23	0.22
13	0.09	0.16	0.17	0.38	0	0.35	0	0.42	0.49	0.20	0.13	0.17			0.23	0.22
14+	0.09	0.16	0.17	0.38	0	0.35	0	0.42	0.49	0.20	0.12	0.17			0.23	0.22

length and weight were similar for walleye and lake whitefish, and asymptotic length was similar for splake and burbot. Smallmouth bass reached the shortest asymptotic length, while splake reached the lowest asymptotic weight.

Predator Mortality

Total instantaneous mortality rates varied greatly among predator species (Table 6). The total instantaneous mortality rate was highest for splake and lowest for lake whitefish. Total instantaneous mortality rates were similar for burbot and brown trout, and for smallmouth bass and

Table 7. Abundance at age of predators in Chequamegon Bay, Lake Superior, during 2001.

Age (years)	Lake Whiefish	Walleye (native)	Walleye (stocked) Kakagon	Walleye (stocked) Ashland	Lake Trout (native)	Lake Trout (stocked)	SM Bass	Burbot	Splake	B Trout (native)	B Trout (stocked)	Northern pike
1	5,226	1,770,338	6,683	27,413	214,228	0	6,110	23,763	93,150	3,404	88,503	131,613
2	3,955	910,029	39,636	0	90,181	0	3,984	13,753	22,018	2,034	842	53,885
3	2,993	467,794	0	3,439	37,951	0	2,598	7,959	2,938	1,216	503	22,061
4	2,265	240,466	0	0	15,971	0	1,694	4,606	3,083	727	301	9,032
5	1,714	123,610	0	7,178	6,721	0	1,104	2,666	173	434	180	3,698
6	1,297	63,541	0	3,285	2,829	0	720	1,543	194	259	107	1,514
7	982	32,663	0	0	1,190	13,786	470	893	0	155	64	620
8	743	16,790	0	885	501	20,667	306	517	23	93	38	254
9	562	8,631	6	246	211	10,423	200	299	9	55	23	104
10	426	4,437	5	128	89	3,202	130	173	3	33	14	43
11	322	2,281	3	80	37	2,363	85	100	1	20	8	17
12	244	1,173	0	0	16	169	55	58		12	5	7
13	184	772	2	0	7	113	36	34		7	3	3
14	140	508		23	3	0	24	19		4	2	1
15	106	334		0	1	0	15	11		3	1	
16	80	220		13		0	10	7		2	1	
17	60	145		8		53	7	4		1		
18	46	95		3		0	4	2				
19	35	63		4		0	2	1				
20	26	41		1		0	1					
21	20	27				5						
22	15	18				2						
23	11	12										
24	9	8										
25	7	5										
26	5	3										
27	4	2										
28	3	1										
29	2											
30	1											

lake trout. The instantaneous fishing mortality rate was highest for splake and lowest for lake whitefish. Burbot and smallmouth bass had zero instantaneous fishing mortality rates and similar instantaneous natural mortality rates.

Table 8. Average and percentage of total available prey biomass in Chequamegon Bay, Lake Superior, 1995–1998.

Scientific Name	Tons	Percentage
Lepomis macrochirus	0.24	0.001
Oncorhynchus tshawytscha	0.32	0.002
Culaea inconstans	0.59	0.003
Prosopium coulteri	1.79	0.009
Osmerus mordax	6.17	0.031
Cottus ricei	8.72	0.044
Notropis volucellus	9.73	0.049
Prosopium cylindraceum	9.92	0.050
Oncorhynchus kisutch	10.44	0.053
Salvelinus namaycush - stocked	10.82	0.055
Etheostoma nigrum	11.18	0.057
Moxostoma macrolepidotum	14.00	0.071
Salvelinus fontinalis X S. namaycush	22.94	0.116
Ictalurus nebulosis	28.28	0.143
Notropis atherinoides	33.16	0.168
Catostomus catostomus	34.07	0.173
Salvelinus namaycush - native	39.37	0.199
Notropis hudsonius	71.95	0.364
Salmo trutta	90.12	0.456
Pungitius pungitius	125.28	0.634
Gymnocephalus cerunns	127.25	0.644
Lota lota	138.00	0.699
Percina caprodes	179.48	0.909
Coregonus clupeaformis	194.4	0.984
Ambloplites rupestris	406.87	2.060
Perca flavescens	648.80	3.286
Cottus cognatus	655.30	3.318
Micropterus dolomieui	928.84	4.704
Percopsis omiscomaycus	1,009.95	5.114
Sander vitreum	1,072.07	5.429
Catostomus commersoni	13,856.91	70.172
Total	19,747	

Predator Abundance

Coolwater predators (smallmouth bass, northern pike and walleye) made up 85% of total predator abundance in Chequamegon Bay, whereas coldwater predators (lake whitefish, lake trout, brown trout, splake and burbot) made up only 15% of total predator abundance in Chequamegon Bay. Walleye (3.7 million individuals) and lake trout (420,779 individuals) were the most abundant predators at all ages, whereas smallmouth bass (17,555 individuals) were the least abundant predator at all ages (Table 7).

Prey Abundance

The estimated total available prey biomass averaged 19,747 tons and ranged from 9,253 to 39,420 tons during 1995-1998 (Table 8). Of the total average available prey biomass of all sizes, white sucker was the most abundant prey and composed 70% of available prey biomass. Trout-perch, yellow perch, slimy sculpin, rockbass *Ambloplites rupestris*, walleye, and smallmouth bass were the next most abundant species (2-5% of available prey biomass). Remaining species each made up less than 1% of the total available biomass.

Predator Consumption

Lake whitefish consumed the most prey per individual over their lifetime, 0.27 tons of prey per predator, whereas other predators each consumed between 0.02 and 0.23 tons of prey per predator over their lifetime (Table 9). Brown trout lifetime consumption per individual was only slightly lower than that of lake whitefish. Smallmouth bass and splake had the lowest lifetime prey consumption per individual, and lifetime consumption per individual for walleye and lake trout were similar.

Total consumption of prey by all predators in Chequamegon Bay was 6,362 tons, of which 94% was fish (5,957 tons) (Table 9). Walleye consumed the most prey, approximately 4688 tons per year, and accounted for 74% of total predator consumption in Chequamegon Bay. Remaining predators consumed 713 tons or less of prey per predator. Coolwater predators (smallmouth bass, northern pike and walleye) consumed 79% of total prey consumption, whereas coldwater predators (lake whitefish, lake trout, brown trout, splake, and burbot) consumed only 21% of total prey consumption.

Rainbow smelt were consumed more than any other prey and were the predominant prey of walleye, splake, lake whitefish, and lake trout (Table 9). Coolwater predators consumed 96% of all yellow perch consumption, though splake and brown trout also consumed yellow perch. Walleye, northern pike, splake, smallmouth bass and brown trout consumed 31% of the total available yellow perch biomass in Chequamegon Bay. Walleye were the primary predator of salmonines in Chequamegon Bay, and consumed 90% of total salmonine consumption.

Gross conversion efficiency varied widely among predators (Table 10). Lake whitefish had the lowest gross conversion

Table 9. Total prey consumption (tons) by each predator species in Chequamegon Bay, Lake Superior, in 2001.

Species	Walleye	Lake Trout	Northern Pike	Brown Trout	Splake	Lake Trout	Burbot	SM Bass
Crustaceans	0.04	130	0	00	1	9	7	0.01
Crayfish	104	0	4	0	0	0	0.17	4
Other Invertebrates	6	65	8	40	5	21	1	0.11
Rainbow Smelt	2806	393	83	101	152	24	7	1
Yellow Perch	109	0	79	0.24	8	0	0	2
Coregonines	447	22	16	0.73	0.46	0.50	5	0
Salmonines	349	0	13	0	24	0	0	0
Other Fish	867	103	145	129	36	8	19	7
Prey per individual	0.10	0.10	0.11	0.23	0.04	0.27	0.07	0.02

Table 10. Gross conversion efficiency (g/g) by age for each of the predator species in Chequamegon Bay, Lake Superior, 2001. Values are expressed as percentages.

Age	Lake Whitefish	Walleye	Lake Trout	Smallmouth Bass	Burbot	Brown Trout
1	0.75	10.33	13.05	11.81	4.43	12.32
2	3.34	14.23	7.88	14.18	7.17	9.63
3	4.18	13.21	7.65	17.21	12.06	12.58
4	4.50	11.96	7.15	17.99	11.89	12.38
5	4.34	10.64	6.60	23.14	11.31	11.99
6	6.08	14.37	6.06	23.28	10.59	11.52
7	5.73	13.52	5.59	23.07	9.85	11.08
8	5.36	12.73	5.57	22.63	9.17	10.68
9	5.02	12.02	7.33	22.04	8.56	10.30
10	4.69	11.41	7.00	21.80	8.03	9.97
11	4.41	10.86	6.70	21.22	7.56	9.69
12	4.15	10.37	6.42	20.68	7.16	9.46
13	3.92	9.97	6.17	20.25	6.82	9.26
14	3.73	9.60	5.96	19.79	6.52	9.07
15	3.57	9.29	5.75	19.44	6.28	8.94
16	3.43	9.02		19.12	6.07	8.84
17	3.31	8.79	7.71	18.90	5.89	8.70
18	3.21	8.59		18.67	5.73	
19	3.12	8.42		18.52	5.59	
20	3.05	8.28		18.34		
21	2.99	8.15	10.06			
22	2.93	8.04	4.50			
23	2.89	7.95				
24	2.85	7.87				
25	2.82	7.80				
26	2.80	7.73				
27	2.77	7.69				
28	2.75	7.65				
29	2.74					
30	2.73					
All Ages	3.59	9.48	6.84	19.92	7.44	10.03

Note: Calculations are based on year simulations. Gametes shed are included in the estimation of gross conversion efficiencies.

efficiency for all ages combined. Splake had the lowest gross conversion efficiency at ages 8-11. Smallmouth bass had the highest gross conversion efficiency for all ages combined and at all ages older than age 2. Gross conversion efficiency was highest for most species and occurred at the age of sexual maturation.

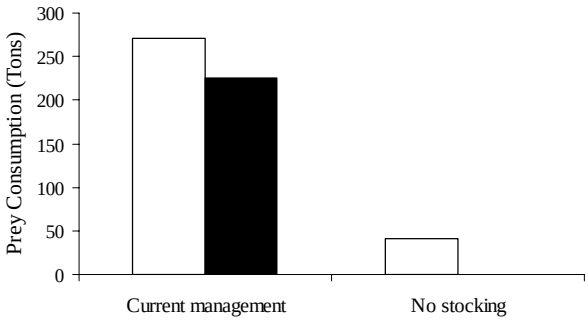

Figure 10. Reduction of annual prey consumption after elimination of stocking of brown trout (white) and splake (black) in Chequamegon Bay, Lake Superior, 2001.

Effect of Management Actions on Predator Consumption

Simulated management scenarios resulted in small changes in prey consumption in Chequamegon Bay. Enacting minimum length limits for walleye (18 inches) and smallmouth bass (20 inches) reduced prey consumption

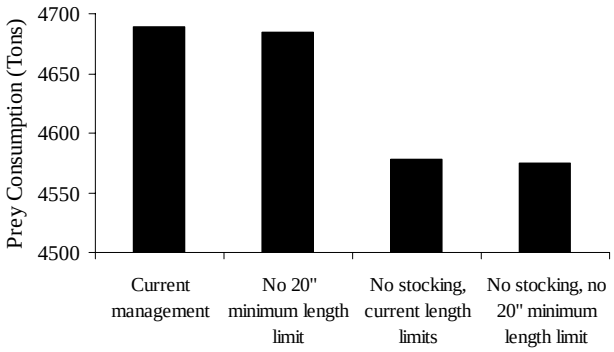

Figure 11. Effect of simulated management scenarios on walleye annual prey consumption in Chequamegon Bay, Lake Superior, 2001.

by only 9.0%. Eliminating stocking of brown trout, splake and walleye reduced prey consumption by only 456 tons (8.9%; Figure 10). Eliminating walleye stocking reduced

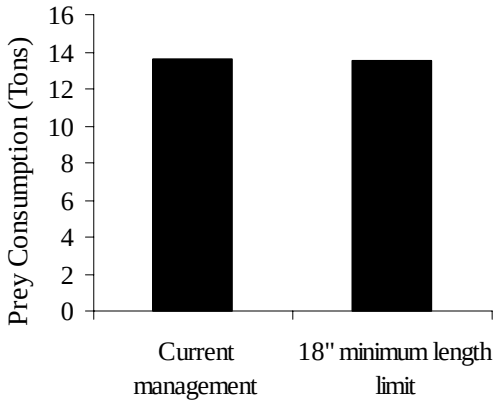

Figure 12. Effect of changng the minimum length limit on smallmouth bass from 22-inches to 18-inches on annual prey consumption in Chequamegon Bay, Lake Superior, 2001.

prey consumption by walleyes by only 112 tons (1.8%), eliminating walleye stocking and eliminating the 20-inch minimum length limit on walleye reduced walleye prey consumption by only 115 tons (1.8%), and eliminating the minimum length limit on walleye reduced prey consumption by walleyes by only 5 tons (0.08%; Figure 11). Enacting an 18-inch minimum length limit on smallmouth bass reduced prey consumption by 201 kilograms (0.001%; Figure 12).

Discussion

Predator Diet Composition

Lake trout diets in Chequamegon Bay were similar to other studies of lake trout diets in Lake Superior (Conner et al. 1993; Ebener 1995; Negus 1995; Gallinat 2000), though seasonal trends differed, perhaps because of differences in prey availability between Chequamegon Bay and the rest of Lake Superior. Historically, coregonine species, such as lake herring and deepwater ciscoes, were the preferred prey of lake trout (Dryer et al. 1965). However, with the decline of coregonine populations and the introduction of rainbow smelt into the Great Lakes, lake trout began to feed predominantly on rainbow smelt (Conner et al. 1993). Inshore, where distributions of lake trout and rainbow smelt overlap, lake trout switch to eating progressively more coregonines and fewer rainbow smelt (Conner et al. 1993). We found that this dietary shift was only apparent with older lake trout in Chequamegon Bay, as was found for older lake trout in western Lake Superior (Ebener 1995; Mason et al. 1998).

Brown trout and splake diets in Chequamegon Bay differed from other studies of brown trout and splake diets in Lake Superior (Conner et al. 1993; Ebener 1995), because brown trout ate fewer aquatic invertebrates in Chequamegon Bay than in Lake Superior, perhaps because we sampled too few brown trout diets to detect seasonally important prey items in Chequamegon Bay. In addition, the occurrence of small prey fishes in diets of brown trout and splake differed between our study and previous studies (Conner et al. 1993; Ebener 1995). In addition, cool water prey species were included in higher proportions in our study, which may reflect habitat and prey availability.

Burbot fed on similar prey in Chequamegon Bay as in western Lake Superior, except burbot diets included less amphipods and more coolwater species in Chequamegon Bay than in western Lake Superior (Bailey 1972; WDNR unpublished data). Mysis were previously more predominant in burbot diets (Bailey 1972) than in more recent studies, which indicates that foraging patterns may be changing. In addition, burbot previously ate coregonines in large proportions in January and late summer (Bailey 1972), but more recently, burbot eat coregonines throughout the year (WDNR, unpublished data; this study), perhaps because coregonine populations are increasing in Lake Superior (MacCallum and Selgeby 1987). In Green Bay, burbot fed on similar species, with similar seasonal trends, as burbot in Chequamegon Bay, except that burbot eat more alewives in Green Bay (Rudstam et al. 1995), where alewives are much more abundant than in Chequamegon Bay. In Green Bay, as in this study, burbot ate a higher proportion of coolwater prey species.

Lake whitefish fed predominantly on rainbow smelt after the age of 6 in Chequamegon Bay, which has not been found elsewhere. Lake herring in the Apostle Islands region of Lake Superior preyed on rainbow smelt in winter, which suggests that planktivores are capable of eating fish (Hoff et al. 1997), perhaps because of competition or increased energy demand. Abundance of coregonine species is increasing in Lake Superior (MacCallum and Selgeby 1987), which could be causing increased competition among young age classes. The diet shift may occur to reduce competition for limited prey at a time when lake whitefish energy demand increases with sexual maturation. Lake whitefish become sexually mature at age 6, so they may switch to more energetically profitable prey at that age.

Walleye fed on more prey species in Chequamegon Bay than in western Lake Superior and the St. Louis River (Mayo 1997; Swenson 1977). Walleye fed exclusively on rainbow smelt in western Lake Superior (Swensen 1977), whereas walleye fed mostly on rainbow smelt, with a wide variety of other prey species, in Chequamegon Bay. In contrast, walleye did not feed on rainbow smelt in high proportion until after age 11, and yellow perch were important prey for age 2-10 walleye (15% of diets) in the St. Louis River, western Lake Superior (Mayo 1997). In Chequamegon Bay, yellow perch was only an important prey for a few age classes of walleye (15-25% of diets). Differences in diet between walleye in Chequamegon Bay and the St. Louis River may reflect differences in prey preferences, prey availability, or predator avoidance. Walleye in Chequamegon Bay could be selecting for soft-rayed prey and avoiding spiny-rayed fishes, as has been shown for walleye elsewhere (Hartman and Margraf 1992; Knight and Vondracek 1992). Rainbow smelt use Chequamegon Bay as a nursery area, (Hoff and Bronte 1999), which may cause high densities of young rainbow smelt during the year and influxes of mature rainbow smelt during spring to spawn (Heist and Swenson 1993; Buckner 1995). Walleye use pelagic prey during summer (Swenson 1977), and rainbow smelt are pelagic when young (Lantry and Stewart 1993) or in turbid water (Heist and Swenson 1993). Yellow perch, unlike rainbow smelt, may have developed effective predator-avoidance behavior through co-evolution with walleye.

Northern pike and smallmouth bass fed on many of the same species in Chequamegon Bay as in the St. Louis River (Ogle et al. 1996; Mayo 1997), although importance of prey species differed between the two areas. Rainbow smelt

was not a major prey of northern pike and smallmouth bass in the St. Louis River, perhaps because of high availability of rainbow smelt in Chequamegon Bay (Heist and Swenson 1993, Buckner 1995). Crayfish was also not a common prey for smallmouth bass in Chequamegon Bay (12% all ages combined; this study) or in the St. Louis River (17% all years combined; Mayo 1997), whereas crayfish were important prey for smallmouth bass in other waters (Rabeni 1992; Weidel et al. 2000). In Chequamegon Bay, smallmouth bass fed on readily available prey that are more energetically profitable and less costly to handle than crayfish.

Thermal History

Chequamegon Bay heated faster in spring than the St. Louis River, though average water temperatures were much lower after April in Chequamegon Bay than in the St. Louis River (Mayo 1997). Chequamegon Bay is several degrees cooler than the St. Louis River because warm surface waters in the bay are replaced with cold water, or warm water in the bay is displaced by cold water being forced into the bay (Ragotzkie et al. 1969). Water temperature cools faster in autumn in Chequamegon Bay (2.6°C in November) than in Lake Superior (4.4-7.0°C in November; Ebener 1995; Negus (1995). In Chequamegon Bay, water temperature decreased rapidly after October, when strong storms thoroughly mix waters in the bay with cold, deep water from Lake Superior. Low temperatures in Chequamegon Bay during winter months were similar to those from other studies (Ebener 1995; Negus 1995). In Chequamegon Bay, average water temperature decreased more quickly in autumn, but warmed more quickly in spring than in Lake Superior, a pattern that is consistent with the bay freezing and thawing before the rest of the lake.

Prey Abundance

Prey abundance may have been underestimated in Chequamegon Bay, because bottom trawls underestimate prey biomass due to the distribution of species in the water column, trawl avoidance by fish, and gear inefficiency (Brandt et al. 1991). For example, age 0-1 rainbow smelt are distributed near the thermocline in the Great Lakes, where they are unavailable to summer bottom trawling (Lantry and Stewart 1993). Rainbow smelt use Chequamegon Bay as a nursery area (Hoff and Bronte 1999), so most rainbow smelt in the bay during summer are age 1 and are distributed in the water column at the time of trawling. Age 0 yellow perch are also pelagic and remain unavailable to bottom trawls until they reach a length of 30-mm, when they become demersal (Ney and Smith 1975). Other prey species, such as lake herring and lake whitefish, are pelagic, so are not fully vulnerable to capture in bottom trawls. Distribution of fish species in the water column is also affected by water clarity; so erosion of red-clay sediments that reduces water clarity in Chequamegon Bay after storm events (Ragotzkie et al. 1969) could reduce vulnerability of most species to bottom trawls. During periods of high turbidity, rainbow smelt are suspended in the water column during the day instead of near the bottom (Heist and Swenson 1993). Time of day, size and fish density also affect vulnerability to trawling. Trawl net avoidance by fish is greater during the day and increases with fish size (Francis and Williams 1995), and high fish density ahead of the trawl increases fish escapement and avoidance (Godo et al. 1990). Some species are able to out-swim the net (Suuronen et al. 1997), swim away from the oncoming vessel (Pitcher et al. 1996), or swim with the trawl to escape when towing speed is reduced to haul in the net (Misund et al. 1999). Gear inefficiency is also caused by the inability to trawl in depths less than 1.5-meters, which precludes sampling in some productive habitats in Chequamegon Bay.

Prey abundance may also have been underestimated in Chequamegon Bay, because movement of prey species into Chequamegon Bay from Lake Superior was not measured. Rainbow smelt are known to spawn in Chequamegon Bay (Hoff and Bronte 1999), however, movement of rainbow smelt during the remainder of the year is poorly understood. In addition, commercial catches indicate that prey species, such as lake herring and other coregonines, move between Chequamegon Bay and Lake Superior. Temperature and habitat may keep small prey species from moving out of Chequamegon Bay into Lake Superior. Abundance of prey species in Chequamegon Bay, as influenced by movement of prey species into the bay from Lake Superior, may be reflected in patterns of prey use by predators.

Predator Consumption

Lake whitefish consumed more prey per individual over their lifetime than any other predator species in Chequamegon Bay. High consumption per individual by lake whitefish may partially be explained by errors in the bioenergetics model. Parameters in the coregonid model may overestimate consumption by 20% (C. Madenjian, USGS, personal communication). Lake whitefish activity parameters were replaced with parameters from the lake trout swimming speed sub-model to account for this bias, but a low total annual mortality rate and low gross conversion efficiency may also explain high lake whitefish consumption estimates. A commercial fishery for lake whitefish does not operate in Chequamegon Bay, so the total annual mortality rate on lake whitefish was low (24%), in contrast to the total annual mortality rate in the Apostle Islands (63%), where a large commercial fishery operates (WDNR unpublished data). Low gross conversion efficiency may reflect poor fit of the model to data or an inability of lake whitefish to digest prey fish. Other studies have shown that a bioenergetics model for coregonines accurately predicted growth (Helminen et al. 1990, Rudstam et al. 1994), but these studies did not test predictions of consumption or test the model specifically for lake whitefish.

Estimated gross conversion efficiencies for all predators except lake whitefish in Chequamegon Bay were within the range for other piscivores (Brett and Groves 1979). Gross conversion efficiency is an indicator of diet adequacy, ration level, state of health, and environmental suitability for a fish (Brett and Groves 1979). High conversion efficiency is equated with fast growth (Stewart et al. 1983; Diana 1995). Smallmouth bass experienced the fastest growth of all predator species in Chequamegon Bay, and total and age-specific gross conversion efficiency of smallmouth bass was nearly double that of any other species. Walleye gross conversion efficiency was similar to that found elsewhere for walleye of various sizes at varying temperatures (Kelso 1972). Total gross conversion efficiency for lake trout was 6.23% in Minnesota waters of Lake Superior (Negus 1995), which is similar to our estimate for lake trout in Chequamegon Bay. In contrast, the gross conversion efficiency for lake trout was higher in Lake Michigan (12.2%; Stewart et al. 1983) and for burbot in Green Bay (10.7%; Rudstam et al. 1995) than we found for the same species in Chequamegon Bay. Higher conversion

efficiency in Lake Michigan than in Chequamegon Bay could be due to differences in seasonal temperatures and productivity (Lantry and Stewart 1993).

Consumption of all predator populations except burbot and lake whitefish was greatest at age 1, the age of maximum abundance. In contrast, burbot consumption peaked at age 2, as in Green Bay (Rudstam et al. 1995), and lake whitefish consumption peaked at age 5. The similar age of peak consumption for burbot in Green Bay and Chequamegon Bay may be a result of burbot preying mainly on small fish species, which have a lower energy density than coregonines or rainbow smelt. Lake whitefish peak consumption probably occurred at age 5 because lake whitefish fed only on invertebrates until age 6, and therefore may have needed to eat large quantities of this prey to obtain enough energy.

Eliminating stocking or changing angling regulations had little effect on consumption by predators in Chequamegon Bay. Walleyes, which are mostly self-sustaining, consumed more prey than any other predator in Chequamegon Bay, so eliminating stocking of walleye reduced consumption by this species by only a small amount. In contrast, eliminating stocking of brown trout and splake, which are mostly stocked, eliminated nearly all consumption by these species in the bay. However, brown trout and splake would likely continue to migrate into Chequamegon Bay from Lake Superior to feed, so only a small decrease in consumption by these species would be expected if stocking were moved out of the bay. Decreasing the minimum length limit of smallmouth bass reduced consumption by only a small amount because smallmouth bass larger than 18-inches were uncommon. Eliminating the daily bag limit of one walleye over 20-inches decreased consumption only slightly because estimated abundance of large walleye was low.

Predator consumption may not have been accurately estimated because some predator species were not included in the analysis (due to small sample size), physiological parameters were borrowed, or because of errors in input variables in the bioenergetics model. Coho and Chinook salmon were not modeled, because too few were sampled, though both species move through Chequamegon Bay at some times of year, and both species have higher consumption rates than other salmonines in Chequamegon Bay (Stewart et al. 1981; Ebener 1995; Negus 1995). Physiological parameters were lacking for brown trout and splake, and were therefore borrowed from lake trout. Parameter borrowing between species is common in bioenergetics modeling, but can lead to errors in consumption estimates if energetics vary significantly among species (Ney 1990, 1993; Rudstam et al. 1995). Growth of brown trout and splake were assumed to be similar to lake trout, but we assume that errors in consumption estimates due to differences in the allometric functions of consumption and respiration of brown trout and splake are small because errors in internal parameters create small errors in predicted consumption (Kitchell et al. 1977; Stewart et al. 1983; Bartell et al. 1986). Recent studies have modeled brown trout consumption in Lake Superior and Lake Michigan as being intermediate between other salmonine species, while consumption by splake was ignored (Stewart et al. 1981; Stewart and Ibarra 1991; Ebener 1995). Effects of predator populations are based on estimates of abundance and mortality, so estimates of consumption are highly sensitive to errors in estimates of abundance and mortality (Hewett 1989). We minimized errors in mark-recapture estimates of cool-water species abundance by using multiple gears for marking and recapture (Pierce 1997). Underestimating abundance of coldwater species in late fall through early spring would not greatly affect consumption estimates because consumption decreases with water temperature and is minimal at cold temperatures (Diana 1995). Estimating mortality from catch curves is precise and accurate if age is estimated accurately and if mortality and recruitment do not vary systematically with age (Van Den Avyle and Hayward 1999).

Management Implications

Bioenergetics models are useful for predicting predator consumption on prey fish populations and for predicting the effect of management actions (Stewart et al. 1981; Luecke et al. 1994; Perry et al. 1995). Prey consumption by smallmouth bass in Chequamegon Bay was negligible, so simulating a decrease in the minimum length limit to 18-inches did not greatly reduce prey consumption. Splake and brown trout consumption in Chequamegon Bay was minimal. Walleye and northern pike preyed on salmonines, so stocking of splake and brown trout was partially supplementing their diets instead of building stocks for angler harvest. Because little is known about salmonine movement into Chequamegon Bay, shifting salmonine stocking outside the bay may not reduce predation of these species in the bay. Walleyes consume the greatest amount of prey in Chequamegon Bay, but eliminating stocking and the 20-inch minimum length limit, would likely have little effect on total consumption.

Although prey fish biomass may have been underestimated for some species, average available prey fish biomass still exceeded annual predator consumption; suggesting that prey abundance is currently not limiting predator growth and abundance in Chequamegon Bay. Prey abundance is difficult to accurately estimate with bottom trawls, and prey abundance is often underestimated by relying on one gear type, so hydroacoustics may be useful for estimating prey biomass in Chequamegon Bay, as in Lake Michigan and Lake Superior (Brandt et al. 1991; Heist and Swenson 1993). More accurate estimates of prey abundance in Chequamegon Bay, in turn, would increase the accuracy of bioenergetics modeling of the effects of predator demand on prey populations.

Improved estimates of predator abundance would strengthen the accuracy of estimated predator demand in Chequamegon Bay since predator abundance has the greatest effect on predicted consumption. Reproduction by stocked walleye and brown trout was assumed negligible, however successful reproduction would mean that we underestimated the abundance of these species in Chequamegon Bay. We do not know if walleye spawning along the Ashland shoreline leads to recruitment of adult walleye in Chequamegon Bay. The extent of natural reproduction by stocked walleye and brown trout should be determined. In addition, movement of coldwater predators into Chequamegon Bay would directly affect their abundance in the bay. Most predator movement into the bay appears to occur during fall and winter, as suggested by creel survey data (WDNR unpublished data). Individual consumption rates decrease with cooler water temperatures, so increased abundance of coldwater predators in fall and winter may have a negligible effect on total predator consumption. Nonetheless, the timing and rate of movement of coldwater predators into Chequamegon Bay

needs further investigation. Estimates of post-stocking mortality also are needed because they had a direct effect on abundance. Lastly, data were missing on diets, growth, mortality, and abundance of other predators, such as rainbow trout, coho salmon, and Chinook salmon. These species have all been shown to be efficient predators (Stewart et al. 1981, Ebener 1995, Negus 1995), so their abundance, growth, diet, mortality, and movement into Chequamegon Bay should be quantified.

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Corresponding author: (MJH) hansenm@uwsp.edu
Current address: (JAD) Memorial University, St. John's, New Foundland

APPENDIX A. Lake trout diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table A1. Proportion of diet items (wet weight) by age for lake trout in Chequamegon Bay, Lake Superior, 1998-2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crustaceans	Other Inverts
1	0		23.0	0	0	0	2.0	52.0	23.0
2	0		52.0	0	0	0	22.0	12.0	15.0
3	18	14	61.1	0	37.5	0	1.4	0	0
4	24	15	90.2	0	3.2	0	6.6	0	0
5	29	20	96.4	0	3.6	0	0	0	0
6	34	24	98.4	0	0	0	0	0	1.6
7	15	6	100.0	0	0	0	0	0	0
8	27	9	65.1	0	34.9	0	0	0	0
9	22	6	45.2	0	49.4	0	5.4	0	0
10	24	9	34.0	0	65.0	0	1.0	0	0
11	13	5	39.9	0	55.4	0	4.7	0	0
12+	30	10	15.8	0	78.9	0	5.3	0	0.1

Note: Diet of age 1 and 2 lake trout taken from Negus (1995).

Table A2. Proportions of diet items by wet weight in the "Other Fish" and "Other Invertebrates" diet category by age for lake trout in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Plecoptera	Mayfly	Ninespine Stickleback	Alewife	Lamprey	Spottail Shiner
1						
2						
3	0.0	0	4.6	0	0	2.0
4	0.0	0	0	0	0	0
5	1.6	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0.4	0	0	5.1
9	0	0	0	0	1.0	0
10	0	0	0	2.6	0	2.2
11	0	0.1	0	4.0	0	1.3
12+	0	0	0	0	0	0

Table A3. Seasonal proportions (wet weight) of prey items for lake trout of ages 3-7 in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Coregonines	Other Fish	Invertebrates
1	50.0	0	50.0	0
61	0	0	100.0	0
66	100.0	0	0	0
79	30.7	0	69.3	0
84	100.0	0	0	0
111	100.0	0	0	0
183	100.0	0	0	0
184	0	0	100.0	0
252	100.0	0	0	0
253	100.0	0	0	0
259	100.0	0	0	0
261	100.0	0	0	0
267	100.0	0	0	0
274	100.0	0	0	0
276	0	100.0	0	0
280	100.0	0	0	0
287	100.0	0	0	0
288	100.0	0	0	0
290	100.0	0	0	0
292	100.0	0	0	0
295	100.0	0	0	0
297	98.4	1.6	0	0
320	100.0	0	0	0
365	50.0	0	50.0	0

Table A4. Seasonal proportions (wet weight) of prey items for lake trout of ages 8 and older in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Coregonines	Other Fish	Invertebrates
1	100.0	0	0	0
61	100.0	0	0	0
66	84.1	15.9	0	0
84	28.0	72.0	0	0
88	99.9	0	0	0.1
111	98.7	0	1.3	0
122	100.0	0	0.0	0
123	0	100.0	0	0
128	0	99.9	0	0.1
129	100.0	0	0	0
134	0	0	0	100.0
183	19.9	0	80.1	0
184	35.4	0	64.6	0
248	0	100.0	0	0
254	0	0	100.0	0
276	0	100.0	0	0
288	100.0	0	0	0
289	100.0	0	0	0
292	100.0	0	0	0
365	100.0	0	0	0

APPENDIX B. Brown trout diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table B1. Proportion of diet items by wet weight of brown trout by age in Chequamegon Bay, Lake Superior, 1998-2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Amphipods	Other Inverts
1	11	5	57.5	0	29.6	0	11.0	0	1.9
2	40	23	57.3	0	0	0	42.2	0	0.5
3	46	16	46.4	0.9	0	0	49.0	0	3.7
4	20	4	96.7	0	0	0	3.3	0	0
5	14	5	63.3	7.3	0	0	29.2	0	0.2
6+	5	2	0	0	0	0	100	0	0

Table B2. Proportions of diet items by wet weight in the "Other Fish" and "Other Invertebrates" diet category of brown trout by age in Chequamegon Bay, Lake Superior.

Age	Plecoptera	Mayfly	Caddisfly	Leech	Ruffe	Trout Perch	Ninespine Stickleback	Emerald Shiner	Unknown Minnow
1	0	0	0.11	1.79	0	0	0	10.97	0
2	0	0.49	0	0.01	0	0	14.58	26.32	1.31
3	3.58	0.04	0	0	0.48	4.10	34.10	10.01	0.33
4	0	0	0	0	0	0	0.44	0	2.83
5	0	0.17	0.02	0	0	0	29.18	0	0
6	0	0	0	0	0	0	0	100	0

Table B3. Seasonal proportions (wet weight) of prey items for brown trout of all ages in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Other Fish	Invertebrates
1	0	0	0	86.0	14.0
14	0	0	0	86.0	14.0
16	100	0	0	0	0
61	70.8	0	0	29.2	0
66	100	0	0	0	0
79	0	1.8	5.9	92.3	0
84	100	0	0	0	0
85	99.7	0	0	0	0.3
86	100	0	0	0	0
89	0	0	0	67.6	32.4
92	100	0	0	0	0
97	0	0	0	99.7	0.3
110	0	0	0	100	0
111	0	0	0	100	0
129	0	0	0	100	0
136	0	0	0	0	100
184	0	0	0	100	0
218	72.6	0	0	27.4	0
290	74.1	0	0	0	25.9
295	0	0	0	0	100
307	100	0	0	0	0
365	0	0	0	86.0	14.0

APPENDIX C. Splake diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table C1. Proportion of diet (wet weight) by age for splake in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crustaceans	Other Inverts
1	103	67	70.6	0	0	0	29.1	0.04	0.27
2	70	28	82.2	0	2.7	0	14.4	0.7	0.03
3	29	8	46.3	10.1	0	14.2	29.5	0	0
4	15	2	0	0	0	0	100	0	0
5	5	1	0	0	0	0	100	0	0
6+	10	3	11.9	0	0	0	15.7	0	72.4

Note: Crustaceans include Diporeia hoyi, Mysis relicta and Bythotrephes only.

Table C2. Proportions of diet items by wet weight in the "Other Fish" and "Other Invertebrates" diet category by age for splake in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Ninespine Stickleback	Emerald Shiner	Spottail Shiner	Johnny Darter	Sculpin	Trout Perch	Amphipods	Bythotrephes	Unknown Inverts	Annelids	Odonata	Mayfly
1	17.25	5.93	1.14	0	2.96	1.85	0.04	0	0.25	0.01	0	0.02
2	4.49	3.99	0	0.73	0	5.17	0.22	0.45	0.03	0	0	0
3	24.52	0.40	0	0	4.57	0	0	0	0	0	0	0
4	6.25	0	0	0	93.75	0	0	0	0	0	0	0
5	100.00	0	0	0	0	0	0	0	0	0	0	0
6+	15.72	0	0	0	0	0	0	0	72.38	0	0	0

Table C3. Seasonal proportions (wet weight) of prey items for splake of all ages in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crustaceans	Other Invertebrates
1	100.0	0	0	0	0	0	0
11	100.0	0	0	0	0	0	0
17	14.1	0	0	0	0	0	85.9
25	100.0	0	0	0	0	0	0
38	100.0	0	0	0	0	0	0
61	61.2	0	0	0	38.4	0.4	0
66	72.1	0	0	0	27.8	0	0.1
79	0.0	0	0	0	99.2	0	0.8
84	82.1	0	2.0	0	15.6	0.3	0
111	96.8	0	0	0	0	3.2	0
129	100.0	0	0	0	0	0	0
130	0.0	0	0	100.0	0	0	0
182	56.4	0	0	0	43.6	0	0
183	0.0	96.2	0	0	3.8	0	0
234	100.0	0	0	0	0	0	0
249	0.0	0	0	0	100.0	0	0
259	69.9	0	0	0	30.1	0	0
287	100.0	0	0	0	0	0	0
288	100.0	0	0	0	0	0	0
290	85.8	0	0	0	14.2	0	0
292	84.2	0	0	0	15.8	0	0
294	100.0	0	0	0	0	0	0
295	0.0	0	0	0	0	0	100.0
298	81.1	0	0	0	18.9	0	0
314	87.1	0	0	0	12.9	0	0
365	100.0	0	0	0	0	0	0

APPENDIX D. Burbot diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table D1. Proportion of diet items (wet weight) by age for burbot in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crustaceans	Other Inverts
1	0		0	0	0	0	0	0	0
2	0		0	0	0	0	0	0	0
3	0		0	0	0	0	0	0	0
4	0		0	0	0	0	0	0	0
5	0		0	0	0	0	0	0	0
6	3	3	81.2	0	0	0	2.09	16.73	0
7	4	2	18.1	0	0	0	81.94	0	0
8	4	4	96.0	0	0	0	0	3.95	0
9	4	4	80.9	0	0	0	19.13	0	0
10	3	3	99.8	0	0	0	0	0	0.23
11	6	4	52.1	0	0	0	47.89	0	0
12	2	1	100.0	0	0	0	0	0	0
13	4	3	25.4	0	73.8	0	0.81	0	0
14	3	2	0	0	0	0	100.00	0	0
15+	1	10	7.8	0	91.6	0	0.37	0.16	0.03

Note: Crustaceans include Diporeia hoyi, Mysis relicta and crayfish.

Table D2. Seasonal proportions (wet weight) of prey items for burbot of ages 1-2 in Chequamegon Bay, Lake Superior. Diet taken from Fratt (1991). Day 1 is June 1st.

Day	Smelt	Coregonines	Other Fish	Inverts	Crayfish	Crustaceans
1	5.27	1.90	55.27	6.68	0.28	30.61
365	5.27	1.90	55.27	6.68	0.28	30.61

Table D3. Seasonal proportions (wet weight) of prey items for burbot of ages 3+ in Chequamegon Bay burbot, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Coregonines	Other Fish	Invertebrates	Crayfish	Crustaceans
1	100	0	0	0	0	0
24	96.18	0	0	0	3.82	0
66	13.15	86.54	0	0.04	0.26	0
79	6.18	93.82	0	0	0.00	0
84	14.92	82.55	1.74	0.03	0.76	0
110	0	0	100	0	0	0
111	28.30	0	71.70	0	0	0
122	0	0	100	0	0	0
128	0	0	100	0	0	0
214	0	46.57	53.43	0	0	0
214	0	46.57	53.43	0	0	0
253	0	93.13	6.87	0	0	0
280	100	0	0	0	0	0
287	100	0	0	0	0	0
290	23.01	0	76.99	0	0	0
356	0	0	0	0	0	100
363	100	0	0	0	0	0
365	100	0	0	0	0	0

Table D4. Proportions of diet items by wet weight in the "Other Fish" and "Other Invertebrates" diet category for burbot of all ages in Chequamegon Bay, Lake Superior 1998–2001.

Age	Crayfish	Amphipods	Unknown Inverts	Plecoptera	Ninespine Stickleback	Trout Perch	Log Perch	Sculpin
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	16.56	0.17	0	0	0	0	0	2.09
7	0	0	0	0	0	0	0	81.94
8	3.95	0	0	0	0	0	0	0
9	0	0	0	0	0	0	19.13	0
10	0	0	0	0.23	0	0	0	0
11	0	0	0	0	0	38.80	0	9.10
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0.81
14	0	0	0	0	67.77	0	0	32.23
15+	0.16	0	0.03	0	0.21	0	0	0.16

APPENDIX E. Lake whitefish diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table E1. Proportion of diet items (wet weight) by age for lake whitefish in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crustaceans	Other Invertebrates
1	2	2	0	0	0	0	0	100	0
2	19	14	0	0	0	0	0	64.9	35.1
3	4	4	0	0	0	0	0	0.0	100.0
4	9	8	0	0	0	0	0	27.3	72.7
5	13	6	0	0	0	0	0	0	100
6	25	19	83.1	0	0	0	13.3	2.9	19.8
7	55	43	82.4	0	0	0	15.2	1.7	32.1
8	59	46	56.5	0	0	0	40.7	2.4	22.9
9	59	43	74.0	0	0	0	23.4	2.6	0.3
10	36	28	21.9	0	0	0	74.6	3.4	1.2
11	21	16	58.5	0	0	0	27.7	13.4	1.2
12	11	7	88.4	0	0	0	9.4	2.2	0
13	7	5	87.9	0	0	0	11.9	0.2	0
14	6	4	96.6	0	0	0	0	3.4	0
15	3	3	0	0	0	0	0	100	0
16	5	3	92.3	0	0	0	7.7	0	0
17	2	2	0	0	15.3	0	84.7	0	0
18	3	2	100	0	0	0	0	0	0
19	2	0	0	0	0	0	0	0	0
20	2	1	100	0	0	0	0	0	0
21	3	0	0	0	0	0	0	0	0
22	2	0	0	0	0	0	0	0	0
23+	2	1	100	0	0	0	0	0	0

Note: Crustaceans includes only Diporeia hoyi, Mysis relicta, and Bythotrephes species.

Table E2. Proportions of diet items by weight in the "Other Fish" and "Other Invertebrates" diet category for lake whitefish in Chequamegon Bay, Lake Superior 1998–2001.

Age	Sculpin	Johnny Darter	Emerald Shiner	Spottail Shiner	Trout Perch	Ninespine Stickleback	Sphaeriidae	Chironomids	Unknown Inverts	Plecoptera	Snail	Fly	Mayfly	Annelids
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	9.1	22.0	2.1	0.5	0	1.1	0	0.2
3	0	0	0	0	0	0	100.0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	67.1	0	0	0	5.6	0	0	0
5	0	0	0	0	0	0	100.0	0	0	0	0	0	0	0
6	13.3	0	0	0	0	0	19.8	0	0	0	0	0	0	0
7	0	0	0	14.0	1.1	0	31.8	0.4	0	0	0	0	0	0
8	0	0.4	0	15.8	24.5	0	3.6	0	0	0	0	0	19.2	0.1
9	3.0	0.1	0	20.3	0	0	0	0.3	0	0	0	0	0	0
10	0	0	0	39.4	35.2	0	1.2	0	0	0	0	0	0	0
11	0	0	0	27.7	0	0	0	1.2	0	0	0	0	0	0
12	0	4.6	0	0	0	4.8	0	0	0	0	0	0	0	0
13	0	0	0	0	0	11.9	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	7.7	0	0	0	0	0	0	0	0	0
17	60.4	0	24.3	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23+	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table E3. Seasonal proportions (wet weight) of prey items for lake whitefish of ages 1-5 in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Other fish	Crustaceans	Other Invertebrates
1	0	0	0	0	100.0
23	0	0	0	0	100.0
66	0	0	0	14.3	85.7
84	0	0	0	66.7	33.3
365	0	0	0	0	100.0

Table E4. Seasonal proportions (wet weight) of prey items for lake whitefish of ages 6+ in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Other fish	Crustaceans	Other Invertebrates
1	91.0	0	0	1.7	2.1	5.2
65	91.4	0	0	3.4	4.2	1.0
83	100.0	0	0	0	0	0
101	0	0	0	0	0	100.0
109	65.2	0	0	34.8	0	0
110	35.0	0	0	65.0	0	0
121	0	0	0	100.0	0	0
122	90.4	0	0	9.6	0	0
127	0	0	0	0	99.5	0.51
128	33.8	0	0	0	66.2	0
135	0	0	0	48.4	0	51.6
182	91.6	0	0	8.4	0	0
183	99.5	0	0	0.5	0	0
263	0	0	20.2	79.8	0	0
301	0	0	0	100.0	0	0
318	100.0	0	0	0	0	0
342	90.5	0	0	0	0	9.5
365	91.0	0	0	1.7	2.1	5.2

APPENDIX F. Walleye diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table F1. Proportion of diet items (by wet weight) by age for walleye of all ages in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number with Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Crustaceans	Other Inverts
1	29	15	100	0	0	0	0	0	0	0.02
2	30	16	83.2	16.8	0	0	0	0	0	0
3	92	40	93.1	0.8	0	5.6	0.47	0	0	0.04
4	121	58	92.5	0	0.99	0	6.5	0	0	0.03
5	138	68	99.2	0	0	0	0.79	0	0	0.02
6	136	63	96.5	0	0	0	3.5	0	0	0.08
7	141	63	78.0	6.9	0	0	15.1	0	0	0.02
8	65	36	90.3	0	0	0	9.4	0.31	0	0.01
9	52	24	90.0	0	0	0	9.6	0	0	0
10	36	15	97.6	0	0	0	2.0	0	0	0.38
11	30	16	67.1	0	13.3	0	19.6	0	0	0.03
12	21	8	61.2	22.9	0	0	15.9	0	0	0.06
13	25	11	58.6	0	20.7	0	20.6	0	0	0.04
14	15	8	99.1	0	0	0	0.92	0	0	0
15	6	3	100	0	0	0	0.0	0	0	0
16	11	7	99.7	0	0	0	0.28	0	0	0
17	10	2	97.8	0	0	0	0	0	0	2.2
18	5	0	0	0	0	0	0	0	0	0
19	3	2	23.7	25.9	17.7	0	32.8	0	0	0
20+	18	16	53.7	0	44.8	0	1.2	0.29	0	0.01

Table F2. Proportions of diet items by weight in the "Other Fish" and "Other Invertebrates" diet categories for walleye of all ages in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Ninespine Stickleback	Burbot	Smallmouth Bass	Emerald Shiner	Spottail Shiner	Alewife	Johnny Darter	Bullhead	Ruffe	Slimy Sculpin	Unknown Inverts	Mayfly
1	0	0	0	0	0	0	0	0	0	0	0	0.02
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0.47	0	0	0	0	0	0	0	0	0	0.01	0.03
4	0.15	0	5.83	0.50	0	0	0	0	0	0	0	0.03
5	0.20	0	0	0	0.15	0	0	0	0	0.44	0	0.02
6	0.34	0	0	2.99	0.13	0	0	0	0	0	0	0.08
7	0.64	0	0	2.41	0.07	11.95	0	0	0	0	0	0.02
8	1.88	0	0	3.64	1.61	0	0.42	0	0	1.85	0	0.01
9	2.41	0	0	5.24	0.23	0	0	0	0	1.71	0	0
10	0	0	0	0	2.00	0	0	0	0	0	0.35	0.03
11	0.20	15.36	0	0	0.36	0	0	0	0	3.68	0	0.03
12	8.82	0	0	7.06	0	0	0	0	0	0	0	0.06
13	0	0	0	0	0	0	0	20.61	0	0	0	0.04
14	0.92	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0.28	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	2.23
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	32.80	0	0	0
20+	0	0	0	0	0.43	0	0	0	0.80	0	0	0.01

Table F3. Seasonal proportions (wet weight) of prey items for walleye of all ages in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Amphipods	Other Invertebrates
1	100	0	0	0	0	0	0	0
4	100	0	0	0	0	0	0	0
11	100	0	0	0	0	0	0	0
12	100	0	0	0	0	0	0	0
14	66.4	0	33.4	0	0	0	0	0.2
15	100	0	0	0	0	0	0	0
16	99.8	0	0	0	0	0	0	0.2
17	99.4	0	0	0	0	0	0	0.6
18	96.6	0	0	0	0	0	0	3.4
20	98.8	0	0	0	0	0	0	1.2
21	99.9	0	0	0	0	0	0	0.1
22	100	0	0	0	0	0	0	0
23	100	0	0	0	0	0	0	0
24	100	0	0	0	0	0	0	0
28	99.9	0	0	0	0	0	0.1	0
29	100	0	0	0	0	0	0	0
30	98.3	0	0	0	0	1.4	0	0.2
31	99.8	0	0	0	0	0	0	0.2
32	99.7	0	0	0	0	0	0	0.3
79	58.1	0	2.6	0	39.3	0	0	0
84	100	0	0	0	0	0	0	0
85	99.4	0	0	0	0.6	0	0	0
88	76.8	0	0	23.2	0	0	0	0
89	100	0	0	0	0	0	0	0
90	100	0	0	0	0	0	0	0

Table F3 Continued.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Amphipods	Other Invertebrates
91	100	0	0	0	0	0	0	0
92	100	0	0	0	0	0	0	0
93	96.0	4.0	0	0	0	0	0	0
94	93.1	6.9	0	0	0	0	0	0
99	100	0	0	0	0	0	0	0
100	100	0	0	0	0	0	0	0
101	90.0	0	0	0	10.0	0	0	0
102	100	0	0	0	0	0	0	0
103	100	0	0	0	0	0	0	0
105	100	0	0	0	0	0	0	0
106	100	0	0	0	0	0	0	0
110	86.5	0	0	0	13.5	0	0	0
111	79.4	0	0	0	20.6	0	0	0
121	55.4	29.6	0	0	14.9	0	0	0
122	95.7	4.3	0	0	0	0	0	0
123	92.6	0	7.4	0	0	0	0	0
124	82.2	0	0	0	17.8	0	0	0
127	64.6	0	0	0	35.4	0	0	0
128	68.4	0	0	0	31.6	0	0	0
129	66.1	33.9	0	0	0	0	0	0
130	91.8	0	0	0	8.2	0	0	0
133	0	0	0	0	100	0	0	0
134	0	0	0	0	100	0	0	0
154	0	0	0	0	65.9	33.0	0	1.1
184	4.5	0	0	93.0	2.5	0	0	0
260	0	0	100	0	0	0	0	0

Table F3 Continued.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Amphipods	Other Invertebrates
283	0	33.9	23.1	0	43.0	0	0	0
288	0	100	0	0	0	0	0	0
292	22.1	0	40.4	0	37.5	0	0	0
353	100	0	0	0	0	0	0	0
356	100	0	0	0	0	0	0	0
362	100	0	0	0	0	0	0	0
365	100	0	0	0	0	0	0	0

APPENDIX G. Northern pike diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table G1. Proportion of diet items (by wet weight) by age for northern pike in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Other Inverts
1	21	8	22.4	48.8	0	10.7	17.4	0.6	0
2	34	26	11.0	24.2	1.0	6.9	56.9	0	0
3	47	17	9.0	11.2	2.1	9.9	67.5	0.4	0
4	32	14	5.8	9.6	37.1	0	47.6	0	0
5	33	11	3.8	25.2	0	43.3	27.6	0	0.04
6	7	2	100	0	0	0	0	0	0
7	10	1	100	0	0	0	0	0	0
8+	8	6	77.8	0	0	0	22.2	0	0

Table G2. Proportions of diet items by weight in the "Other Fish" and "Other Invertebrates" diet category by age for northern pike in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Plecoptera	Log Perch	Common Shiner	Smallmouth Bass	Trout Perch	Rockbass	Spottail Shiner
1	0	0	11.6	0	0	0	0
2	0	0	0.8	0	11.8	26.7	2.6
3	0	0.3	0	0	0	0	8.5
4	0	2.1	0	7.3	14.0	0	2.1
5	0.04	0	0	0	1.2	12.5	0.7
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8+	0	0	0	0	12.5	0	0

Table G2 Continued.

Age	White Sucker	Ruffe	Ninespine Stickleback	Emerald Shiner	Sculpin	Johnny Darter
1	0	0	1.1	4.7	0	0
2	1.3	11.1	1.1	1.4	0.2	0
3	31.4	23.0	4.2	0	0	0
4	18.7	0	2.5	1.0	0	0
5	0	3.5	0.3	0	9.2	0.2
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8+	0	0	9.6	0	0	0

Table G3. Seasonal proportions (wet weight) of prey items for northern pike of ages 1-2 in Chequamegon Bay, Lake Superior, 1998-2001. Day 1 is June 1st. Values between dates were estimated by linear interpolation in simulations.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Invertebrates
1	0	0	0	0	100	0
10	0	0	6.56	0	93.44	0
13	0	0	0	0	100	0
16	0	0	0	0	100	0
18	0	80,53	18.36	0	0	1.11
23	0	0	0	0	100	0
30	100	0	0	0	0	0
31	100	0	0	0	0	0
32	100	0	0	0	0	0
79	48.56	0	0	19.25	32.18	0.01
102	0	100	0	0	0	0
120	0	90.72	0	0	9.28	0
122	0	52.08	0	0	47.92	0
128	0	77.46	0	0	22.54	0
183	0	0	0	0	100	0
338	31.85	18.38	0	0	49.76	0
353	14.23	0	81.54	0	4.23	0
356	0	0	0	0	100	0

Table G4. Seasonal proportions (wet weight) of prey items for northern pike of age 3 in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Invertebrates	Crayfish
1	0	0	50.00	0	50.00	0	0
11	0	0	0	0	100	0	0
30	100	0	0	0	0	0	0
32	100	0	0	0	0	0	0
52	100	0	0	0	0	0	0
65	0	0	0	0	0	0	100
79	0	0	0	100	0	0	0
84	45.63	0	0	46.75	7.62	0	0
100	100	0	0	0	0	0	0
122	0	0	0	0	100	0	0
338	0	42.17	0	0	57.83	0	0
356	0	0	100	0	0	0	0
365	0	0	50.0	0	50.0	0	0

Table G5. Seasonal proportions (wet weight) of prey items for northern pike of ages 4+ in Chequamegon Bay, Lake Superior, 1998-2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Invertebrates
1	0	0	0	100	0	0
4	0	0	0	100	0	0
12	0	0	0	0	100	0
15	0	0	0	0	100	0
16	0	0	0	0	100	0
24	0	0	0	0	100	0
32	100	0	0	0	0	0
64	0	0	0	0	0	100
79	0	0	0	0	100	0
83	65.03	0	0	0	34.97	0
88	1.80	0	98.20	0	0	0
110	0	0	0	0	97.11	2.89
123	0	0	0	0	100	0
124	100	0	0	0	0	0
133	0	0	0	0	100	0
182	0	0	0	0	100	0
183	4.76	63.09	0	0	32.14	0
290	57.40	0	42.60	0	0	0
338	53.89	40.45	0	0	5.66	0
356	0	0	0	100	0	0
365	0	0	0	100	0	0

APPENDIX H. Smallmouth bass diet information in Chequamegon Bay, Lake Superior, 1998–2001.

Table H1. Proportion of diet items (by wet weight) by age for smallmouth bass in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Number of Samples	Number With Food	Smelt	Yellow Perch	Coregonines	Salmonines	Other Fish	Crayfish	Other Inverts
1	1	0	0	0	0	0	0	0	0
2	24	7	0	81.8	0	0	10.7	7.5	0
3	15	3	0	81.4	0	0	0	18.6	0
4	10	4	0	0	0	0	75.7	24.3	0
5	47	21	2.5	9.2	0	0	66.8	21.0	0.49
6	52	21	0	8.2	0	0	70.5	20.6	0.76
7	36	16	6.4	20.3	0	0	59.3	13.5	0.50
8	38	14	40.2	0	0	0	47.6	12.0	0.24
9	60	26	0	1.7	0	0	82.7	14.5	1.2
10	74	38	16.8	10.3	0	0	54.1	18.3	0.46
11	58	28	38.5	13.6	0	0	42.1	5.7	0.05
12	42	23	29.2	3.6	0	0	62.5	4.7	0.04
13	10	4	91.6	0	0	0	2.8	5.3	0.18
14	3	2	0	0	0	0	100	0	0
15	1	1	98.0	0	0	0	2.0	0	0
16	2	5	33.0	0	0	0	49.8	17.2	0

Table H2. Proportions of diet items by weight in the "Other Fish" and "Other Invertebrates" diet category for smallmouth bass in Chequamegon Bay, Lake Superior, 1998–2001.

Age	Crayfish	Amphipods	Caddisfly	Mayfly	Chironomid	Plecoptera	Unknown Inverts
1	0.00	0	0	0	0	0	0
2	7.50	0	0	0	0	0	0
3	18.64	0	0	0	0	0	0
4	24.32	0	0	0	0	0	0
5	20.98	0.04	0	0.49	0	0	0
6	20.61	0	0	0.76	0	0	0
7	13.48	0	0.01	0.38	0	0	0.11
8	11.98	0	0	0.24	0	0	0
9	14.46	0.05	0	0.86	0	0	0.29
10	18.27	0	0.10	0.16	0	0.20	0
11	5.68	0.05	0	0.05	0	0	0
12	4.70	0	0	0.04	0	0	0
13	5.33	0	0	0.18	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	17.25	0	0	0	0	0	0

Table H2 Continued.

Age	Ninespine Stickleback	Trout	Pumpkinseed	Common Shiner	Johnny Darter	Log Perch	Emerald Shiner	Ruffe	Sculpin
1	0	0	0.00	0	0	0	0	0	0
2	0	0	10.66	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	75.68
5	0	0	0	0	0	0	5.44	54.25	7.12
6	0	0	0	0	6.10	0	3.06	61.30	0
7	0	35.01	0	0	1.47	0	1.84	0	21.01
8	0.60	0	0	0	2.50	23.53	3.82	0	17.13
9	30.33	11.57	0	0	0	0	3.81	0	36.95
10	3.35	0	0	10.02	1.70	0	2.39	11.11	25.54
11	1.93	14.09	1.15	0	0	0	1.43	13.26	10.23
12	0.72	0	0.83	40.09	2.51	5.91	0.96	9.60	1.92
13	0	0	0	0	2.85	0	0	0	0
14	0	0	0	0	100.00	0	0	0	0
15	0	0	0	0	0	0	0	0	1.97
16	0.73	0	0	49.07	0	0	0	0	0

Table H3. Seasonal proportions (wet weight) of prey items for smallmouth bass of ages 1-9 in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Other Fish	Crayfish	Other Invertebrates	Crustaceans
1	0	0	0	97.8	2.2	0
6	0	0	0	97.8	2.2	0
17	0	0	60.0	38.5	0.1	1.3
30	0	7.4	90.0	2.5	0	0.2
79	0	0	93.0	7.0	0	0
84	51.2	0	43.7	5.1	0	0
101	0	91.6	0	8.4	0	0
102	0	60.6	39.4	0	0	0
111	0	0	0	100	0	0
123	0	0	98.8	0	1.2	0
128	0	0	28.4	71.6	0	0
129	0	43.2	12.1	44.5	0.2	0
130	0	0	0	100	0	0
133	0	0	81.2	17.5	1.3	0
134	0	0	97.5	2.3	0.2	0
136	0	0	96.9	0	3.1	0
152	94.7	0	0	0	5.3	0
154	0	21.5	67.2	9.9	1.4	0
365	0	0	0	97.8	2.2	0

Table H4. Seasonal proportions (wet weight) of prey items for smallmouth bass of ages 10+ in Chequamegon Bay, Lake Superior, 1998–2001. Day 1 is June 1st. Values between days between dates were estimated in simulations by linear interpolation.

Day	Smelt	Yellow Perch	Other Fish	Crayfish	Other Invertebrates	Crustaceans
1	0	0	99.6	0	0.2	0.2
6	0	0	99.6	0	0.2	0.2
24	0	0	95.6	4.4	0	0
30	0	0	0	100	0	0
40	0	81.3	0	0	14.9	3.7
79	0	0	78.2	21.8	0	0
84	88.0	0	10.3	1.7	0	0
110	0	0	0	100	0	0
111	0	10.2	88.2	1.7	0	0
122	0	8.0	88.3	3.7	0	0
123	0	0	58.2	41.8	0	0
128	0	68.2	9.2	22.6	0	0
129	0	17.1	67.2	15.6	0.1	0
130	0	0	0	100	0	0
133	0	0	99.6	0	0.4	0
134	0	0	94.2	5.8	0	0
136	0	74.0	9.1	17.0	0	0
152	0	0	63.0	35.8	1.2	0
154	0	0	30.7	66.5	2.8	0
365	0	0	99.6	0	0.2	0.2