NIWA
Taihoro Nukurangi

Potential effects of tench (*Tinca tinca*) in New Zealand freshwater ecosystems

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Executive Summary

Tench (*Tinca tinca* L.) were introduced to New Zealand in 1868. They are a cyprinid fish, belonging to the same family as goldfish, rudd, and koi carp. They are currently being spread (illicitly) to new waters by coarse fish angling enthusiasts. These liberations have raised concerns that tench may interfere with native species and/or contribute to environmental degradation.

As there is no published information on the biology and ecology of tench in New Zealand, this review was undertaken to provide a better picture of their likely role in New Zealand's freshwaters and to assess the potential risks that they might present. Information is gained mainly from the overseas literature, however, this is often of limited value because introduced species can behave very differently in New Zealand, especially if their natural predators and control agents are lacking. Initial data on tench in a New Zealand lake were therefore analysed as part of this review and are presented to help determine the likely role of this species in New Zealand ecosystems.

In general, the tench is limited to relatively slow-moving, shallow waters but has a wide tolerance of environmental conditions within such waters. It is a benthivorous species and although it has the ability to consume zooplankton as well as a wide range of benthic invertebrates, it does not feed on other fish. It is a solitary, secretive, and mainly nocturnal species so is seldom observed. However, it is not rare, and its populations can be relatively high in certain lakes.

High densities of tench have been blamed for large reductions in benthic invertebrates in some overseas lakes, and there is good evidence from both overseas and New Zealand that high density populations can reduce lake water clarity in shallow lakes. Some concerns over the potential role of tench in New Zealand lakes are therefore warranted. However, high-density populations generally contain small, stunted fish that are not favoured by anglers. There is therefore a common interest in 'not stocking' waters where tench are likely to become highly abundant. This begs the question, can such waters be predicted? There are good overseas data on the conditions and habitats that will maximise tench recruitment, but there are very few data on the sources of mortality that control and limit tench populations. This is especially so in New Zealand where their natural predators are lacking. Until better information on factors limiting population size is available, illicit stocking could well result in the degradation of some lakes. Where tench are stocked with other cyprinid species such as goldfish, rudd, and koi carp, they can be expected to combine with such species to disturb sediments, increase nutrient recycling, and amplify top-down effects on zooplankton, especially in shallow lakes. These processes accelerate eutrophication and this degrades water quality, reduces habitats for fish such as smelt and trout, and it reduces lake amenity values.

1. INTRODUCTION

The tench (*Tinca tinca* L.*)* is a European fish that is still an important, albeit small, component of commercial catches in many large European lakes (Ziliukiene & Ziliukas 1998; Grosch et al. 2000). Today, interest in the culture of tench is increasing rapidly in southern Europe (c.f., Billard et al. 1995; Reader 1998) and the aquaculture of this species may soon replace the harvest of wild fish as the main commercial source.

The tench is also a major sports fish in Europe and it forms an important part of the "coarse fish" fishery in England. Tench were successfully introduced to New Zealand in 1968 for sports fishing (McDowall 1990a). This is currently its main use here and the recent, if illicit, spread of tench within New Zealand has been to create new recreational fisheries. To date, the spread of tench throughout New Zealand has not raised any major concerns (McDowall 1987; 1990b). Although this may be because they have had no major impact here, it could also be because of a lack of knowledge.

Tench belong to the family Cyprinidae, which contains numerous species of fish present mainly in the northern hemisphere. No cyprinids occur naturally in New Zealand, however, the family includes other species of carp, including common carp (*Cyprinus carpio*), as well as other warm water fish such as rudd (*Scardinius erythrophthalamus*) and goldfish (*Carassius auratus*). Some cyprinid fish have a reputation for causing ecological damage in lakes overseas (e.g., Tatrai et al. 1996; Bergman et al. 1999), so the role of tench in New Zealand waters needs to be carefully examined.

In this report, I present data from the scientific literature on the biology, ecological requirements, and role of tench in aquatic ecosystems overseas as a basis for predicting its potential spread and impact in New Zealand waters. The sources of information for this review include a range of key scientific papers on the biology of tench and a search of web-based databases including Aquatic Sciences and Fisheries Abstracts, the ISI Web of Science, Fishbase and BISON (Biotic Information System of New Mexico). Although such overseas information is indicative of the likely role of tench in New Zealand waters, it must be remembered that New Zealand lacks many of the species that normally control and limit the spread and population size of introduced species. To help address this limitation, the available information on the growth, size, population density and ecology of tench in New Zealand is also presented.

2. Legal status

Tench were classified as an acclimatised fish under the Fisheries Act 1983. In 1987, the Conservation Act provided for the listing (through an Order in Council signed by the Governor General) of 'sports fish' to be managed by Fish & Game Councils. Fish and Game Councils therefore have the responsibility for sports fish throughout New Zealand, including the licensing of anglers to fish for tench. Fish & Game Councils are charged with developing a fishery management plan for sports fish within their jurisdiction. In addition to securing the sustainability of sports fishing for a particular species in a given water, this plan 'shall have regard to the impact that the management proposed in the draft is likely to have on other natural resources and other users of the habitat concerned' (Section 17L (4b)).

3. Biology and ecology

3.1 Description and genetics

Tench are relatively large (maximum length 70 cm), olive-green to dark bronze coloured, and are found mainly in shallow, still or slow-moving freshwater environments. They have large soft-rayed fins, two barbels, and red eyes, which together with their small scales are their most distinctive features. Adult tench are readily distinguished from all other species by these features, and useful keys and diagnostic information are provided in McDowall (1990a) and Fishbase (2004). Tench are renowned for their slime production and are also known as the 'doctor' fish because of the reputed curative value of this mucous layer.

Sexual dimorphism is often apparent, with males having larger pelvic fins than females. Males also have enlarged second fin rays and a muscular protuberance extending from the flank (Vainikka 2003; Coad 2003). However, Muus et al. (1967) indicated that such dimorphism is only apparent after age 2. A further potentially complicating factor in identification of the sexes is that triploid fish may occur naturally in some populations and have intermediate-sized fins. Weatherley (1959) could not reliably identify the sex of fish less than 10-12 cm long in Tasmanian waters on the basis of external appearance.

Although tench are reported to hybridise with a range of other cyprinids, including goldfish, common carp, rudd and orfe (BISON 2003), no primary sources for this information could be found. Colour variants (e.g., golden tench) occur overseas and may represent the results of such hybridisation. Golden tench are thought to have been released into several waters near Auckland in the 1980s (McDowall 1990a), but this has yet to be confirmed.

3.2 Distribution and spread

Tench are a European fish and their natural range is likely to have extended throughout northern Europe encompassing all the rivers of the Baltic, Caspian and Black Sea and extending westward to the Ob and Yenisei River basins in Siberia (Berg 1949). Historical introductions have probably led to an expansion of the natural range further west to Portugal and parts of Spain, south to Greece and parts of Italy, north to Norway and Finland, and east to India. As tench were introduced from England to Ireland in the 18th century, it is possible that they were introduced to England at an earlier date. Between 1895-1922, they were introduced to North America and were widely distributed within the USA. They now occur in the continents of Africa (Tunisia, South Africa, Zimbabwe, Zambia), South America (Chile), and Australia (Tasmania) as well as in island nations including Cyprus, Japan, Indonesia, and New Zealand.

The ecological effects of these introductions were classified as ‘yes’, ‘no’, ‘unknown’ for seven of the 26 countries where introductions had occurred (Fishbase 2004). No effects were listed for the 18th century introduction from England to Ireland, although it is doubtful whether these would have been recognised at that time. Effects were stated as ‘unknown’ for the introductions to USA, Finland, and Tunisia and ‘probably no’ for New Zealand and Portugal. In essence, this summary indicates how little is known about the ecological consequences of tench introductions worldwide. However, it is also clear that they have not been implicated in the decline of native fish species, as have salmonids and live-bearing fish such as *Gambusia*.

3.3 Feeding and diet

Tench are generally bottom dwelling and are thought to use taste and olfactory cues to locate animal prey. Studies of taste reception to improve food palatability for aquaculture purposes indicated a strong preference for the amino acids cysteine and maleic acid (Kasumyan & Prokopova 2001). Several studies have indicated that tench are nocturnal foragers (Herrero et al. 2003; Perrow et al. 1996), so visual cues may be less important than taste and olfactory cues for prey location. This would allow tench to thrive in turbid as well as clear waters.

Tench have no teeth, but have a relatively large mouth, and probably feed using suction to ingest their prey. However, Petridis (1990) also observed tench to feed by using their buccal cavity to squirt water at the surface layer of silt that overlies lake beds. This suspends small interstitial prey such as chironomids, micro-crustacea and oligochaetes in a small cloud of silt, and the tench then ingest these.

Studies of the diet of tench indicate that they feed primarily on benthic macro-invertebrates, although a number of authors also report feeding on zooplankton and adult insecta, indicating mid-water and surface feeding, respectively (Weatherley 1959; Ranta & Nuutinen 1984; Giles et al. 1990; Michel & Oberdorff 1995; Perez-Bote et al. 1998; Gonzalez et al. 2000). Food items recorded for tench include species of zooplankton (cladocerans, copepods, and ostracods), benthic crustacea (amphipods and decapods), benthic insecta (chironomids, odonata, ephemeroptera, hemiptera, corixidae, and hirudinea), and bivalves (gastropoda and small bivalvia). They are therefore capable of preying on most aquatic invertebrates. Larger fish can utilise very small prey and are therefore not restricted to feeding on relatively large prey as occurs for many other freshwater fish.

Weatherley (1959) found that tench fed mainly on zooplankton in Lake Tiberias (Tasmania), with amphipods and insect larvae being increasingly utilised by the larger (> 100 mm) fish. In three other waters, adult tench fed mainly on pulmonate molluscs, oligochaetes and chironomid larvae, respectively. Gonzalez et al. (2000) reported heavy feeding on chironomid larvae in both riverine and lacustrine environments, with crustacea next most important in the lake and gastropods in the river. Few studies of prey selectivity have been carried out. However, Petridis (1990) recorded positive selection for the isopod *Asellus aquaticus* in a section of the Lancaster Canal despite a higher abundance of gastropods and chironomids. Negative selection for chironomids also occurred here.

Overall, tench can be regarded as a generalised, benthic, carnivore (i.e., it is a benthophagous species), with the predominant prey being those which are most readily available. Large, soft-bodied crustacea are probably preferred over smaller prey that are more difficult to obtain (e.g., oligochates and chironomids), or hard-bodied prey (e.g., molluscs). Some reports indicate that tench also feed on algae and macrophytes, however, this is thought to be rare and to occur by mistake, or when benthic invertebrates are scarce (Weatherley 1959; Coad 2003; Wheeler 1969).

There were no readily available studies on the diet of larval and juvenile tench in the wild, however, they can be expected to feed mainly, albeit not exclusively, on small planktonic prey. Information reported by BISON (2003) indicated that larvae will feed on algae, phytoplankton (including blue-green species), zooplankton, rotifers, and water mites. Ranta & Nuutinen (1984) found that small tench preferred large *Daphnia* (1.5-4 mm long) and eliminated these before turning to smaller plankters. Pyka (1997) reported a daily food ration for juvenile tench (weight 44 mg) of about 6.6% at 25ºC.

3.4 Age, growth and size

The maximum length reported for tench is 70 cm (Muus et al. 1967; McDowall 1990a; Coad 2003), however, large adults are more commonly 30-40 cm. Maximum ages vary among locations and range from 11-20 years (L'Abee-Lund 1986; McDowall 1990a; Wright & Giles 1991; Neophitou 1993). Coad (2003) reported a life span of 5-6 years for populations in Turkish dams, 13 years for fish in the Volga delta, and up to 30 years elsewhere.

Tench can be aged from annuli on either scales, opercular bones, otoliths, or fin rays, but which of these is the most useful depends on local conditions. For example, L'Abbe-Lund (1986) found that otoliths and opercular bones were better than scales. However, Sinis et al. (1999) found that whereas age estimation by opercular bones was limited by indistinct 1st and 2nd annuli, age estimation from scales was limited for fish aged older than 3+ because annuli beyond this were indistinct. Wright & Giles (1991) found that all three structures produced similar results up to age 9+.

Neophitou (1993) found that tench grew relatively quickly in Lake Pamvotida, Greece, with fish reaching 79 mm in their 1st year. However, the annual increment slowed to 28 mm by the 4th year and was 20 mm thereafter. Muus et al. (1967) reported sizes of 40-80 mm after the 1st summer, 100-150 mm by the 2nd summer and 200-300 mm by the end of the 3rd summer. Tench grew more slowly in a UK gravel pit (Wright & Giles 1991). Here, tench averaged 20 mm after their 1st year, 80 mm in the 2nd year, 136 mm in the 3rd year, and attained a length over 400 mm in their 11th year.

The growth of males and females was very similar in St Peters Lake (Wright & Giles 1991), but differed between the sexes in Irish and Finnish lakes, with females growing faster than males (Kennedy & Fitzmaurice 1970; Vainikka 2003). Variation in growth rate between years and lakes appears to be linked more to temperature than food supply. L'Abee-Lund (1986) reported that mean air temperature in autumn had a major effect on inter-annual variations in growth rate, probably because it prolonged the growing season.

3.5 Population size and structure, standing crop, and production rate

The population size of tench varies between environments, and has been found to range from 126-530 individuals/ha (Lusk et al. 1998; Wright & Giles 1991). Lusk et al. (1998) reported a mean of 367 individuals/ha and a mean biomass of 123.5 kg/ha (range 12.4-260.5). In mixed species communities, tench accounted for 8 % of total fish numbers and about 25 % of the total fish biomass. Wright & Giles (1991) reported a standing crop of 102 kg/ha in St Peters Lake (UK), which had abundant vegetation, but only 0.5 kg/ha in the more turbid, weed-free Main Lake. Tench accounted for 29 % of total fish biomass in St Peter's Lake. Zhiliukene (1993) indicated that the production of tench could be up to 4.3kg/ha.

The sex ratio of tench in New Mexico was reported as 1:1 (BISON 2003). In Finland it is thought to be close to 3:1 (females: males), however, this may be caused by selective mortality of the smaller males (Vainikka 2003). Data presented by Wright & Giles (1991) also indicate a prevalence of females (56 %) even though the growth rates, and hence sizes of males and females, were very similar.

3.6 Maturation, spawning and fecundity

Tench can mature as early as age 2+ at a size of 90 g (males) and 110 g (females) (Sanchez-Herrera et al. 1997). However, age at first maturation is likely to vary between locations depending on growth rate and water temperature. Neophitou (1993) reported that both sexes of tench in a Greek population matured first at age 3+. Yilmaz (2002) reported ages of 3-4, and in the more northern and colder waters of Finland, tench don't become sexually mature until they are 4-5 years old (Vainikka 2003). In experiments designed to determine the effect of temperature on tench reproduction, Horoszewicz et al. (1977) found that females in a warm pond matured earlier, had higher fecundities, and spawned more often than tench in a colder pond.

Tench spawning also appears to be closely controlled by water temperature, but the temperature at which spawning occurs varies. Gray & Dauble (2001) indicated that spawning occurred in late spring when water temperatures were 10-16 ºC. Neophitou (1993) reported spawning in spring when water temperatures ranged from 18-20 ºC. In Dagestan, spawning occurred when temperatures exceeded 19-20 ºC (Shikhshabekov 1977). For at least some populations, the date of first spawning can be predicted by determining the sum of degree-days over 10 ºC (Breton et al. 1980; Horoszewicz 1983). However, photoperiod also influences the timing of spawning (Martin et al. 1999) and so can modify the influence of water temperature. Wright & Giles (1991) indicated that strong year classes occurred during warm summers. Year class strength was positively correlated (r = 0.58) with degree days over 16 ºC.

Spawning occurs in shallow (usually <1 m deep) waters, and tench are broadcast spawners, laying their eggs over aquatic vegetation such as macrophytes and reeds. The eggs stick to the vegetation and are small (0.9-1.0 mm in diameter) and green coloured. Groups of males have been observed following one or more female prior to spawning. The males are believed to be attracted to the females through pheromones released into the water via the gills. Pinillos et al. (2002) found that male sensory systems were strongly activated by free and glucuronidated 17,20 beta-dihydroxy-4-pregnen-3-one (prostaglandins).

Female fecundity is relatively high. Neophitou (1993) reported an average of 184,000 ± 21,200 eggs per kg of fish. Pimpicka (1991) reported fecundities of 85,700-543,900 eggs per kg of fish. However, not all eggs are spawned at once. Tench are batch spawners and 3-9 spawnings may occur over the spawning season, but not all females participate in each (Horoszewicz 1983). In colder climates, there may be fewer spawnings per season. For example, Shikhshabekov (1977) reported only 2 for tench in Dagestan.

Incubation of eggs occurred in 76 hours at a mean water temperature of 19.6 ºC (Penaz et al. 1981), and the highest incubation rate (89.4 %) occurred at 22.9 ºC with fry hatching after 48 hours (Kouril et al. 1988). On hatching, larvae are about 3.8 mm long (Penaz et al. 1981). As with some other cyprinids, tench larvae have attachment organs, which allow them to hang onto the under-surfaces of plants (Coad 2003). Exogenous feeding occurred after 11 days at a length of 5.6 mm (Penaz et al. 1981). Tench larvae can be expected to be free-swimming at this stage.

3.7 Habitats and migrations

Adult tench inhabit a range of waters characterised by low water velocities, soft substrates (e.g., mud, silt or sand), and the presence of some aquatic vegetation. Such habitats include the lower reaches of rivers, off-river habitats such as oxbows, river deltas, the shallow margins of lakes, drainage canals, estuarine areas, wetlands, and shipping canals (Bouvet et al. 1984; Townsend & Peirson 1988; Rossier 1995; Pilcher & Copp 1997; Donnelly et al. 1998; Gonzalez et al. 2000; Coad 2003). In general, they inhabit the shallower regions of such habitats.

BISON (2003) indicated that tench are found mainly in large rivers/streams with mean flows over 28 m^3/s, presumably because in such large rivers there are large areas of low-velocity water in the lower reaches. In lakes, they prefer near-shore sites, presumably because of the presence of shallow vegetated habitat (Rossier 1995). Szajnowski (1970) found a strong relationship between the catches of tench in 53 Mazurian lakes over 40 ha in area and the ratio of littoral zone to total lake area.

Tench are generally benthic and forage for food mainly at night, covering a wide search area (Perrow et al. 1996). However, Vainikka (2003) indicated that on calm sunny days some fish fed on terrestrial insecta on the water surface. Perrow et al. (1996) followed fish using radio telemetry and found that they were inactive during the day, resting in favoured locations associated with the rush *Typha*. This was thought to be because *Typha* has relatively wide stems that permit access by tench to deep cover. Radio-telemetry studies also indicated that they were relatively sedentary in a side arm of the Rhone River (Bouvet et al. 1984), but that they migrated to and from specific locations in a shipping canal (Donnelly et al. 1998).

Because of their ability to tolerate low oxygen levels (see below), tench can inhabit the deeper, hypolimnetic zones of lakes and ponds during summer months when oxygen levels are low and these habitats cannot be utilised by most other fish species (BISON 2003). In winter, Coad (2003) reported that tench in Iran were largely inactive and buried themselves in shallow muddy habitats. Such behaviour is likely to occur in severe winters (Wheeler 1969). In a UK river, they preferred the downstream, channelised sections during winter months (Pilcher & Copp 1997).

The micro-habitat of juvenile tench is shallow water with a silty bottom such as the dense, millfoil and pondweed filled off-channel sites in rivers (Copp 1997).

3.8 Tolerances

Tench are often referred to as a warm water fish species and, unlike salmonids (cold water species), they prefer temperatures over 20 ºC. Their preferred temperature is 20-21 ºC and they have a final preferendum of 27.4 ± 0.5 ºC (Perez Regadera et al. 1994). In tanks where a temperature gradient was produced, they inhabited waters between 20-24 ºC, rarely venturing into waters over 25 ºC (Alabaster & Downing 1966). However, they have been reported venturing into waters up to 37 ºC for brief periods (Coad 2003). BISON (2003) indicted an upper lethal temperature of 35.2 ºC. Coad (2003) reported a preferred range of 15-23.5 ºC, and BISON (2003) indicated that growth can occur over the range 12-30 ºC.

Tench are highly tolerant of low oxygen levels (Vainikka 2003; Coad 2003) and can survive in waters where oxygen levels are as low as 0.7 mg/l (BISON 2003).

Adult tench are also highly tolerant of pH and prefer the range 6.5-8.0 (BISON 2003). Mortality increases at levels below 5 and over 10.8. Similar, ranges were reported for larvae. Hamackova et al. (1998) found that larval survival was highest between a pH range of 7-9, but some survival occurred at a pH of 5 as well as 10. Values of 4 and 11 were lethal to all fish.

Tench are tolerant of brackish water. Weatherley (1959) found that although 15.4 ppt was fatal within 24 h, tench were able to withstand 13.8 ppt, albeit with a greatly reduced motor function. Coad (2003) reported a tolerance to 12 ppt salt water. Tench can thrive in brackish waters such as estuaries and the Baltic Sea, where salinities can range from 4-10 ppt (Weatherley 1959).

Tench prefer low water velocities and avoid high-gradient, rapid water. BISON (2003) indicated a maximum water velocity of 0.27 m/s. Tench also prefer shallow waters and BISON (2003) indicated a maximum depth of 7.6 m, however, this is likely to represent the maximum depth at which tench have been captured rather than a maximum depth tolerated.

Tench are reported to be nocturnal, however, this is probably related to predator avoidance rather than intolerance of light. Garcia-Ceballos et al. (1998) found that tench under low light (40 lux) were gregarious, but this behaviour declined as light levels increased up to 200 lux. Tench thrive in both clear and turbid waters, so the high suspended solids levels occurring in turbid lakes are unlikely to affect tench.

3.9 Predators, parasites & diseases

The main aquatic predator of tench is the pike (*Esox lucius*). However, they are also vulnerable to predation by black and large-mouthed bass (BISON 2003; Garcia-Berthou & Moreno-Amich 2000). Broenmark et al. (1995) determined the role of piscivores in a range of Swedish lakes. They found that tench populations in lakes with piscivorous fish were characterised by low population size and a prevalence of large fish. In lakes lacking piscivores, tench populations were large and composed mainly of small fish.

The main parasites of tench have been described by Yildiz (2003) and Ozturk (2002). Helminthes are the main endoparasites and include species such as *Asymphylodae* *tincae*, *Pomphorhynchus laevis*, and *Acanthocephalis lucii* that occur in the intestine; *Ligula intestinalis* and *Pomphorhynchus laevis* that occur in the abdominal cavity; nematode larvae, metacercariae and *Piscicola geometra* that are found in the skin, and *Dactylogyrus macracanthus*, *Argulus foliaceus* and *Ergasilius sieboldi* that occur on the gills. Yildiz et al. (2003) indicated that infection rates for *Ligula* ranged from 41-84 % and declined with fish size.

3.10 Interactions and trophic role

Tench appear to be reduced by introductions of some exotic fish species, including piscivores such as large-mouthed bass (Garcia-Berthou & Moreno-Amich 2000), but their populations were enhanced by eel stocking (Leopold 1986). I found no reports of direct effects by tench on other fish species, however, they have been implicated in reduced densities of some invertebrates. In enclosures, tench reduced gastropods, but not other macro-invertebrates (Beklioglu & Moss 1998; Broenmark 1994). Giles et al. (1990) indicated that, on the basis of their diet and food preferences, trophic overlap could occur between tench, perch and wildfowl in shallow waters.

Tench are known to be selective planktivores and so may exert top-down effects (i.e., a reduction in zooplankton) on some lake ecosystems, thereby increasing phytoplankton and reducing water clarity. Ranta & Nuutinen (1984) demonstrated strong selection by tench for large *Daphnia*, and Perez-Bote & Limpo-Iglesia (1998) found that the zooplankton composition of tench ponds varied seasonally, with *Daphnia* and copepods dominating in winter when tench are inactive, but not in summer when tench are active. Small rotifers dominated the plankton in summer months. Beklioglu et al. (2003) carried out a partial removal experiment in a lake dominated by tench. The tench in this lake fed mainly on zooplankton and a 250 % improvement in water clarity followed removal of 57 % of the total fish stock. This improvement in water clarity was attributed primarily to the top-down role of tench, but common carp were also present in this lake, so they may have also contributed to its turbidity.

Tench may also change lake ecosystems through bottom-up effects on food webs. A number of studies have shown that tench can reduce macrophytes by stimulating greater periphyton growth on macrophyte surfaces (Beklioglu & Moss 1998; Broenmark 1994; Williams et al. 2002). The increased periphyton cover reduces light penetration and nutrient supply to macrophytes, resulting in their decline. The increase in periphyton may be related to removal of browsing gastropods by tench (Beklioglu & Moss 1998; Broenmark 1994) and/or to stimulation of periphyton growth through the increased cycling of inorganic nitrogen through tench excreta (Williams et al. 2002). Phosphorous concentrations were high in all treatments, so were not implicated (Williams et al. 2002). Such effects have only been recorded when densities of tench were relatively high, and Williams et al. (2000) indicated that a biomass in excess of 200 kg/ha may be required for macrophyte reduction. Baughman (1947) reported that tench were regarded as a nuisance in parts of Maryland and Idaho because of their high abundance.

Tench may also increase turbidity in lakes through their foraging activities, but again this would only be expected at high densities when food becomes scarce, and tench are forced to forage in surficial sediments to find small prey. Tench have been observed feeding by ‘squirting’ water at the surface layer of sediment to suspend the overlying silt (Petridis 1990). Tench in South Africa caused an increase in the turbidity of shallow waters by disturbing bottom sediments (de Moor & Bruton 1988)

3.11 Limiting factors

San Juan (1995) listed the main factors known to limit the size of tench populations. These were water level fluctuations, increased exposure to wave action, destruction of fry habitat, and effects of predators. Wolter et al. (2000) indicated that loss of macrophytes could be a factor that limits tench populations in lakes, and Hinrichs (1998) noted the adverse impact of drain maintenance activities, such as removal of vegetation, on tench. Hamackova et al. (1995) found that a temperature reduction below 22 ºC increased the mortality of 2-4 day old fry, but not 7-10 day old fry. The extent of mortality was directly related to the size of the temperature drop.

3.12 Control measures

Tench are generally harvested using trammel nets, however, seine and gill nets are also used. Balik & Cubik (2000) found that trammel nets with an outer wall of multifilament and an inner wall of monofilament were more efficient than other combinations. The CPUE for trammel nets with monofilament inner walls of 28, 40, 50 and 60 mm mesh size was twice as high as for nets with an inner wall of multifilament netting (Balik 2001). Balik & Cubic (2001) also investigated gill nets. They found that red, yellow, brown and blue gill nets of nylon monofilament were more effective on tench than black, white, light green, or dark green nets.

4. Tench in New Zealand

Tench do not form a commercial fishery in New Zealand and there is currently no interest in them for aquaculture. Their main value is for recreational fishing, particularly among coarse fish anglers. The potential role of coarse fish fisheries in New Zealand waters was previewed by Rowe (1986). Tench are now apparently more sought after by coarse fish anglers because of the large size of specimens caught in New Zealand waters. However, the size of the fishery in New Zealand is small in comparison with that for other freshwater fish species (e.g., trout, salmon, whitebait, eels) and there is little management of the species by Fish & Game Councils.

Tench were introduced to New Zealand in 1868 and were released into slow-moving waters near Oamaru to provide angling opportunities (McDowall 1990a). They remained there until the 1950s, after which they were spread to Wellington in the North Island. By 1986, they had been illicitly spread by coarse fish angling enthusiasts to waters around Christchurch and Nelson as well as to a wide range of waters in the Auckland and Waikato districts of the North Island (McDowall & Richardson 1986). Populations have been found more recently in Nelson, Northland and the Bay of Plenty. Their current distribution is shown in Fig. 1.

Not surprisingly, new populations tend to be close to the major population centres. This indicates that the main vector for their spread is not eel fishermen or accidental transfers via boats or trailers (as for catfish), but the deliberate stocking of fish by angling enthusiasts who choose to disregard the law.

Although tench are a warm water species, it is clear from the tolerances outlined in Section 3.8 that they could colonise suitable waters throughout the North and South Island, and that neither altitude, longitude, nor latitude will limit their potential geographical range. However, anglers don’t generally venture far from home, so the spread of this species can be expected to cluster around major population centres. As large tench are prized by anglers, stocking is also likely to focus more on shallow, weedy ponds and lakes than the larger, deeper, and generally colder, clear-water lakes favoured by salmonids. Where tench are stocked into ponds or lakes with overflows or outlets, fry and juveniles can be expected to eventually spread downstream and to colonise slow-moving or static waters in the lower reaches of rivers and streams within the catchment.

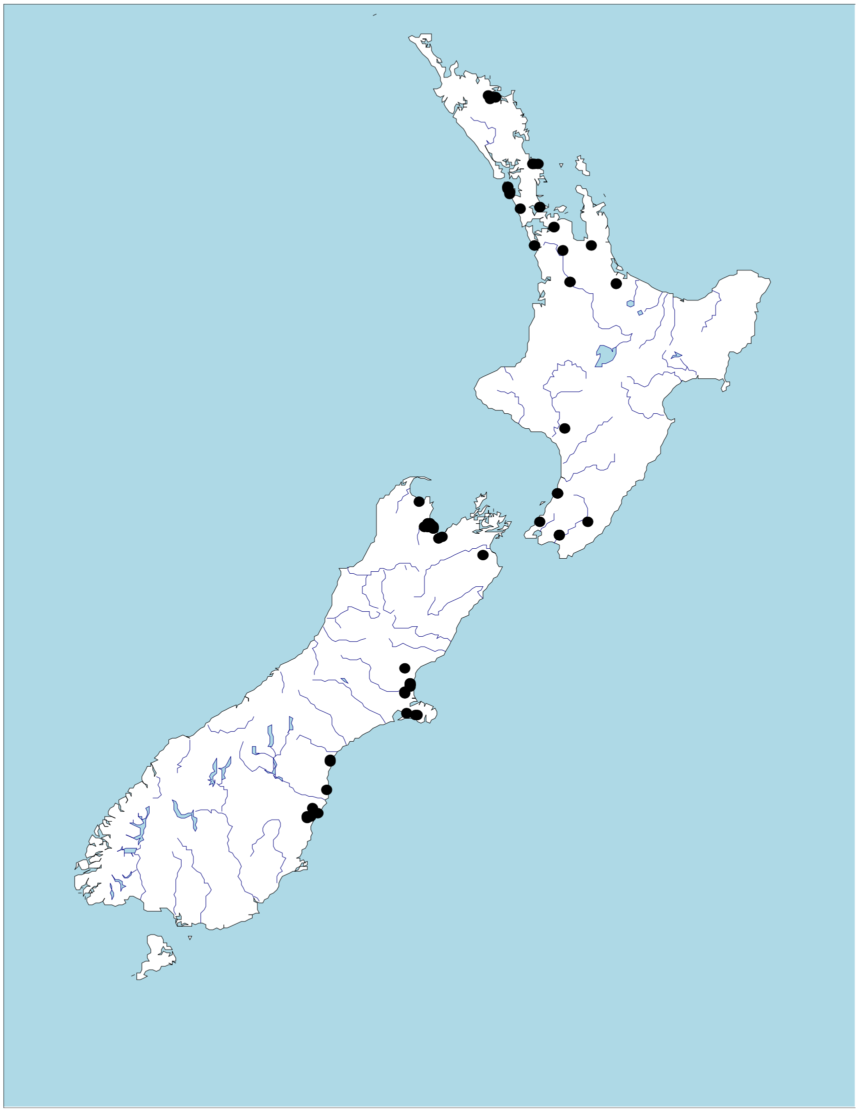

Figure 1: Distribution of tench in New Zealand based on records in the New Zealand Freshwater Fish Database as at February 2004.

There are few natural predators for tench in New Zealand waters. Pike are not present, and the main piscivorous species will include salmonids and possibly large eels. Cormorants are not mentioned as major predators of tench in the UK nor Europe, so shags are unlikely to fulfil this role in New Zealand, except perhaps in clear-water lakes, or when tench are exposed by removal of cover (see below). Their population size can therefore be expected to be relatively high in waters where spawning habitat (shallow, weedy areas) is abundant and where water temperatures are high enough for good egg incubation and larval survival (i.e., over 22 ºC for periods of several days or more).

The only studies on tench in New Zealand were carried out in the late 1970s in a small (2 ha) Auckland lake (Lake Parkinson). Sixty tench were illegally released into this lake in September 1974 when they were about 80 mm long (pers. comm., J Smith). By 1976, it was apparent that a breeding population had developed as a sample of 225 tench revealed fish ranging in size from 4 to 39 cm. The complex, multi-modal size frequency distribution obtained in 1976 (Fig. 2) indicated that there were likely to have been multiple spawnings over summer months (e.g., December-March) in both 1975 and 1976. The original tench had grown from a mean length of 8 cm in 1974 to 30 cm by 1976, indicating an annual increment of approximately 11 cm, or 0.9 cm per month. Juvenile fish (4-6.5 cm TL) were sampled in May 1976, and by September 1976, the corresponding mode in the tench size frequency distribution indicated that they were 11 cm. This indicated that relatively rapid growth had occurred (i.e., 1.3-1.4 cm per month). This is somewhat faster than the 0.99 cm per month for the original stock, but is consistent with the faster growth of young-of-the-year fish. Such growth rates are much higher than those reported for European populations.

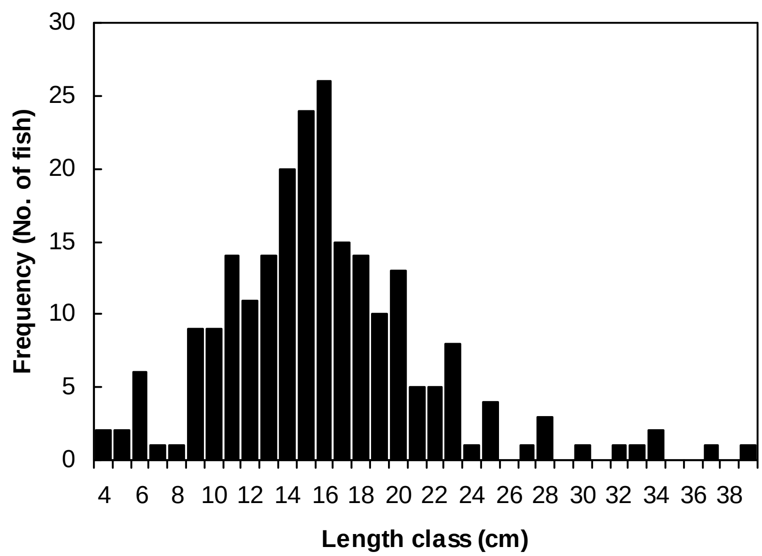

Figure 2: Population size-structure for tench in Lake Parkinson (1976).

The diet of tench was also recorded for fish caught between 1976-1980 in Lake Parkinson Lake (Table 1). The main prey species by percent occurrence (i.e., of fish containing some food) was the cladoceran *Bosmina* (62.2 % in 1976 and 61.1 % in 1977). *Bosmina* were often packed into the stomachs of quite large (FL > 400 mm) fish. It is unlikely that *Bosmina* are taken individually by such large tench as they are relatively small (0.5-1.0 mm diameter). Tench may therefore be able to filter small prey items from the water. Such an ability is in accord with the feeding mode observed by Petridis (1990), in which tench fed on the very small animals present on and within the surface layer of silt by suspending them in a cloud of water and then extracting them from this. Large prey, including chironomid larvae and terrestrial insecta, predominated in tench caught during 1978 and 1980 after aquatic vegetation had been largely removed from the lake by grass carp. Plant fragments and sand were present in a number of tench, but this occurred mainly during winter months when animal prey species were scarce.

Table 1: Stomach contents of tench in Lake Parkinson (1976-1980).

Prey type	**Frequency of occurrence (%)**			
	1976 (n = 71)	**1977 (n = 22)**	**1978 (n = 31)**	**1980 (n = 36)**
Bosmina	62.2	61.1	17.4	5.9
Copepods	6.7	16.7		
Chydoras	6.7			
Mites	13.3			
Amphipods			8.7	
Chironomids	6.7	11.1	69.6	41.2
Byozoans		16.7		
Insecta				41.2
Snails				5.9
Common bully				5.9
Detritus	2.2			47.1
Sand	22.2	22.4		41.2
Plant fragments	28.9	22.4	17.4	23.5
Fish feeding (%)	63.4	81.8	74.2	47.2

The mean CPUE of tench in both fyke nets and Wisconsin traps declined between 1976 and 1978 (Fig. 3) as did the mean size of the tench caught. Taken together, these results indicate a reduction in the number of fish over time, especially the larger-sized fish. Shag predation on tench in the experimental or treatment arm of this lake (i.e., stocked with grass carp) will have increased as weed cover was removed by the carp (Rowe & Champion 1994), but is unlikely to have contributed much to the decline in tench, as a reduction in tench CPUE also occurred in the control arm of the lake where macrophytes remained. The decline in tench numbers between 1976-1978 was therefore attributed mainly to netting and trapping.

When this lake was rotenoned in 1981, a fish census was carried out. The number of tench present at that time was 3,560 and the density was 0.187 fish/ha, or 1 fish for every 5.3 m^2 of lake bed (Rowe & Champion 1994). The standing stock of tench was 72.7 kg. These figures are likely to be lower than normal, as tench densities had already been artificially reduced by netting over the previous 5 years. Excluding the grass carp, which had been stocked into the lake to remove the exotic plants, tench clearly dominated the fish community and accounted for 75.7 % of the total fish biomass.

The tench recovered from Lake Parkinson in October 1981 included a large group of small fish (range 50-90 mm). These were mostly young-of-the-year fish (age 0+), hatched during the previous spring/summer. There were four distinct modes in the size frequency distribution for these young-of-the-year fish (67, 70, 75, 80 mm), and these are likely to reflect at least four spawnings during the 1980/81 summer. There was very little vegetation and no macrophytes or rushes present in Lake Parkinson after January 1979 (Rowe & Champion 1994). Thus, the spawning and recruitment of tench during the 1980/81 summer was apparently not greatly suppressed by removal of vegetation in this lake.

The tench were sexed by internal examination of gonads. Fish (both males and females) could be sexed from their gonads once they reached a size of about 75 mm. However, not all tench contained identifiable gonads, and some quite large fish (up to 150 mm long) were immature. Most fish over 100 mm long had well developed gonads in October, indicating that maturation and spawning could occur during the following summer (i.e., at age 1+).

The sex ratio was strongly skewed towards females. In a sample of 963 fish ranging in length from 75-535 mm, 62.6 % were females. Females were more numerous than males for all size classes of fish, and all fish over 400 mm long were females.

Being a large, benthivorous fish, tench may have been expected to compete with common bullies for food and space in Lake Parkinson, as common bullies are also benthivores and occur on the lake bottom within and below the littoral zone. However, there was little evidence for such an impact in Lake Parkinson. The density and size of bullies was relatively high in this lake despite the presence of tench (Mitchell 1986; Rowe & Champion 1994).

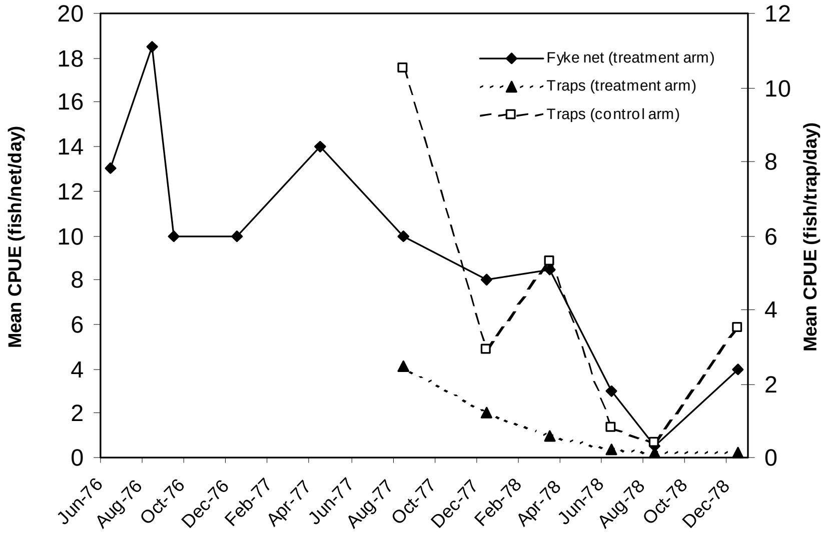

Figure 3: Changes in catch per unit effort (CPUE) of tench in fyke nets and Wisconsin traps in Lake Parkinson between 1976 and 1978.

Overseas studies indicate that tench can exert top-down effects on zooplankton leading to a reduction in water clarity. They can also contribute to increased turbidity levels through their benthic feeding habits. There was no direct evidence for this in lake Parkinson, however, lake water clarity did improve immediately after removal of all fish (Rowe & Champion 1994). As tench were the dominant species, and their main food was the cladoceran, *Bosmina*, it seems likely that they contributed to the reduction in water clarity caused by fish in Lake Parkinson.

5. Summary

It is apparent that tench are unlikely to pose a direct threat to other fish species in lakes and this is likely to include New Zealand's native fish. However, tench have been implicated in environmental changes including reduced invertebrate densities, reduced macrophytes, and/or reduced water clarity in shallow lakes and ponds, both overseas and in New Zealand. Indirect effects on some native fish are possible through reduced food supply, changes in water quality parameters, and a reduction in macrophyte cover.

Indirect effects on native fish aside, the major concern with tench is its potential to degrade lacustrine habitats and the synergistic role it may play in this with other exotic species. This report indicates that there is scope for concern over tench in shallow lakes. However, Rowe (2003) found that both deep and shallow New Zealand, North Island lakes containing large exotic fish, particularly cyprinids, had lower water transparencies than lakes lacking such fish. Cyprinids have a growing reputation for lake degradation mainly via bottom-up effects (e.g., sediment disturbance and nutrient recycling) in Europe. In New Zealand, which lacks many of the natural predators that control the population size of such species, large populations can develop and potentially exert both bottom-up and top-down effects (e.g., reduction of zooplankton) on lake food webs, resulting in a general decrease in water clarity and an acceleration of eutrophication. The introduction of tench into lakes which are vulnerable to such effects (i.e., shallow lakes with large swampy areas allowing good reproduction and survival of tench larvae), or which contain other cyprinids, therefore needs to be strongly discouraged as it can be expected to result in a reduction in both water clarity and amenity value. Where tench have been released into such lakes, monitoring will be required to determine any detrimental changes in the aquatic environment.

Whereas tench can be expected to contribute to reduced water clarity in shallow lakes if large populations develop, they can also be expected to exacerbate the effects of other cyprinids such as koi carp, goldfish and rudd on lake water quality. In addition, tench in combination with rudd can be expected to significantly reduce invertebrate populations in lakes where these fish are both abundant. This effect would be expected to reduce the production of native fish species. Although common bullies appear able to cope with this, other larger native species (e.g., galaxiids) may not be so resilient. At present, there is no indication as to the effects of tench on the macro-benthos (i.e., crayfish and freshwater mussels). The effects of tench on invertebrate densities in lakes is therefore a major gap in current knowledge.

A further issue with tench concerns their potentially high infestation rate with the parasite *Ligula intestinalis*. This large and unsightly worm occurs within the gut of host fish and is already present in a few small lakes north of Auckland. The main vectors for its transfer between lakes are piscivorous birds. It has the potential to spread much more widely if suitable hosts (e.g., tench) and vectors (e.g., shags) are present and widespread. It infects common bullies in New Zealand lakes and would be expected to affect other benthivores, such as the koaro. The spread of tench could potentially increase the incidence of this parasite much more widely within New Zealand.

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