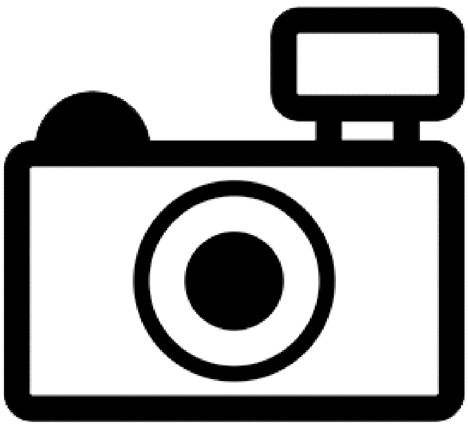
Blue spotted Tilapia (*Oreochromis leucostictus*)
Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, February 2011
Revised, July 2018
Web Version, 5/15/2020

Organism Type: Fish
Overall Risk Assessment Category: Uncertain


No Photo Available

1 Native Range and Status in the United States

Native Range

From Froese and Pauly (2020):

"[In the Democratic Republic of the Congo:] Known from Lake Albert [Thys van den Audenaerde 1963, 1964; Welcomme 1988] and Lake Edward [David and Poll 1937; Poll 1939; Poll and Damas 1939; Verbeke 1959; Thys van den Audenaerde 1963, 1964]. Also reported from affluent rivers and streams of the Semliki River [Trewavas 1983; van Oijen 1995], Rutshuru River and its tributary Molindi River [Poll 1939; Trewavas 1983]."

"[In Uganda:] Reported as native from Lake George [Trewavas 1933, 1983; Poll 1939; Lowe 1957, 1958; Welcomme 1967, 1970; Bailey 1968; Beadle 1981; Hepher and Pruginin 1982; Lowe-McConnell 1982; Noakes and Balon 1982; Wohlfarth and Hulata 1983; Baensch and Riehl 1985; Moreau et al. 1993; Crespi and Ardizzone 1995; Twongo 1995; van Oijen 1995], where it is almost completely limited to habitats inshore [Fryer and Iles 1972], and Lake Albert [Welcomme 1967, 1988; Bailey 1968; Baensch and Riehl 1985], where it occurs in inshore areas and in lagoons [Greenwood 1966]. Also known from Lake Edward (probably native) [Lowe 1957; Welcomme 1967; Bailey 1968; Baensch and Riehl 1985; Crespi and Ardizzone 1995], where it occurs in bays, on exposed shorelines and at the mouths of rivers [Greenwood 1966], from lakes Kachira, Mburo [Mwanja and Kaufman 1995] and Isungo [Trewavas 1983], Kazinga Channel [Trewavas 1933; Poll 1939], and the rivers Mongedo [Baensch and Riehl 1985], Ntotoro (Semliki tributary) and Mongello [Trewavas 1983]. Known from tributaries of the Aswa River, where it is not certain whether it occurs naturally or has been introduced [Trewavas 1983]."

Status in the United States

No records of *Oreochromis leucostictus* occurrences in wild in the United States were found. No information on trade of *O. leucostictus* in the United States was found.

GBIF Secretariat (2020) contains a record of *O. leucostictus* in Alabama. The record information indicates that the specimen was collected from a cage in an experimental fish pond. This does not constitute a record of introduction to the wild.

The Florida Fish and Wildlife Conservation Commission has listed the tilapia *Oreochromis leucostictus* as a prohibited species. Prohibited nonnative species (FFWCC 2020), "are considered to be dangerous to the ecology and/or the health and welfare of the people of Florida. These species are not allowed to be personally possessed or used for commercial activities."

Means of Introductions in the United States

No records of *Oreochromis leucostictus* occurrences in wild in the United States were found.

Remarks

From Froese and Pauly (2020):

"[…] hybridized with *O. spilurus niger* [Fryer and Iles 1972; Siddiqui 1977; Trewavas 1983; Welcomme 1988; 1978], […]"

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

According to Eschmeyer et al. (2018), *Oreochromis leucostictus* (Trewavas 1933) is the current valid name of this species.

From ITIS (2018):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Deuterostomia
      Phylum Chordata
        Subphylum Vertebrata
          Infraphylum Gnathostomata

Superclass Actinopterygii
Class Teleostei
Superorder Acanthopterygii
Order Perciformes
Suborder Labroidei
Family Cichlidae
Genus *Oreochromis*
Species *Oreochromis leucostictus* (Trewavas, 1933)

Size, Weight, and Age Range

From Froese and Pauly (2020):

"Maturity: L_m ?, range 6 - 22 cm
Max length : 36.3 cm SL male/unsexed; [Welcomme 1967]"

Environment

From Froese and Pauly (2020):

"Freshwater; benthopelagic; pH range: 7.0 - 9.0; dH range: 10 - ?; depth range 0 - 10 m [Witte and de Winter 1995]. […]; 26°C - 28°C [Baensch and Riehl 1985; assumed to be recommended aquarium temperature range]; […]"

Climate

From Froese and Pauly (2020):

"Tropical; […]; 2°N - 2°S"

Distribution Outside the United States

Native

From Froese and Pauly (2020):

"[In the Democratic Republic of the Congo:] Known from Lake Albert [Thys van den Audenaerde 1963, 1964; Welcomme 1988] and Lake Edward [David and Poll 1937; Poll 1939; Poll and Damas 1939; Verbeke 1959; Thys van den Audenaerde 1963, 1964]. Also reported from affluent rivers and streams of the Semliki River [Trewavas 1983; van Oijen 1995], Rutshuru River and its tributary Molindi River [Poll 1939; Trewavas 1983]."

"[In Uganda:] Reported as native from Lake George [Trewavas 1933, 1983; Poll 1939; Lowe 1957, 1958; Welcomme 1967, 1970; Bailey 1968; Beadle 1981; Hepher and Pruginin 1982; Lowe-McConnell 1982; Noakes and Balon 1982; Wohlfarth and Hulata 1983; Baensch and Riehl 1985; Moreau et al. 1993; Crespi and Ardizzone 1995; Twongo 1995; van Oijen 1995], where it is almost completely limited to habitats inshore [Fryer and Iles 1972], and Lake Albert [Welcomme 1967, 1988; Bailey 1968; Baensch and Riehl 1985], where it occurs in inshore areas and in lagoons [Greenwood 1966]. Also known from Lake Edward (probably native) [Lowe 1957; Welcomme 1967; Bailey 1968; Baensch and Riehl 1985; Crespi and Ardizzone 1995], where it occurs in bays, on exposed shorelines and at the mouths of rivers [Greenwood 1966], from lakes Kachira, Mburo [Mwanja and Kaufman 1995] and Isungo [Trewavas 1983], Kazinga Channel [Trewavas 1933; Poll 1939], and the rivers Mongedo [Baensch and Riehl 1985], Ntotoro (Semliki tributary) and Mongello [Trewavas 1983]. Known from tributaries of the Aswa River, where it is not certain whether it occurs naturally or has been introduced [Trewavas 1983]."

Introduced

From Froese and Pauly (2020):

"Introduced in Lake Victoria basin [Kenya] [Lowe 1957; Lever 1966; Seegers et al. 2003], Lake Kanyaboli [Seegers et al. 2003], Lake Naivasha [Lever 1966; Fryer and Iles 1972; Siddiqui 1977; Lowe-McConnell 1982; Noakes and Balon 1982; Trewavas 1983; Welcomme 1988; Robotham 1990; Hickley et al. 1994; Muchiri et al. 1995; Okeyo 2003; Seegers et al. 2003] in 1956 [Lowe-McConnell 1982] and some dams in Kenya [Lowe 1957; Seegers et al. 2003]. According to Welcomme (1988) […] this species was introduced in 1954 from Lake Albert, Uganda, into Kenyan waters of Lake Victoria; it has also established in Lake Naivasha [Welcomme 1988]. Reported from the Sondu-Miriu River, up to 9km upstream, and the Nzoia River [Balirwa 1979; Ochumba and Manyala 1992]."

"Introduced [to areas of the Democratic Republic of the Congo where it is not native] from Uganda and reported from the Lualaba River, but success not sure [Welcomme 1988]. Also introduced from Lake Albert to the Ituri area [Decru 2015] and Upper Uele, but only 1 doubtfull [sic] record for the latter [Thys van den Audenaerde 1964]."

"Introduced in upper and middle Akagera [Rwanda]; a record of [sic] [Snoeks et al. 1997] from Lake Kivu needs confirmation [De Vos et al. 2001]."

"Introduced in 1954 from Lake Albert to Lake Victoria [Tanzania] [Bailey 1968; Welcomme 1988; Eccles 1992; Genner et al. 2018; Shechonge et al. 2018] and fish ponds in its catchment [Eccles 1992]. It has since been spread throughout much of Tanzania as an accidental contaminant of farm strains of *Oreochromis niloticus* founded from Lake Victoria [Genner et al. 2018]. This includes Pangani River [Shechonge et al. 2018], Wami River [Shechonge et al. 2018], Ruvu River [Shechonge et al. 2018], Ruaha River [Shechonge et al. 2018], Lake Eyasi [Shechonge et al. 2018], Lake Tanganyika [Shechonge et al. 2018], Malagarazi River [Shechonge et al. 2018], Lake Rukwa [Shechonge et al. 2018] and Lake Malawi [Shechonge et al. 2018]."

"Introduced [in areas of Uganda where it is not native] to Lakes Kyoga [Lowe 1957; Greenwood 1966; Trewavas 1983; Ogutu-Ohwayo 1985; Twongo 1995], Nabugabo [Mwanja and Kaufman 1995; Schofield and Chapman 1995], Wamala [Lowe 1957; Greenwood 1966], Salisbury [Lowe 1957] and Victoria [Greenwood 1966; Kanyike 1990], and from Lake Albert [Lowe 1957; Trewavas 1983] to dams near Teso [Lowe 1957; Noakes and Balon 1982; Trewavas 1983]."

"*O. leucosticus* is present in some swamps [in Burundi] used in fishculture. It is commonly fished in the swamps of Gatumba (North Tanganyika Lake) where it has proved to be more competitive than other species of the same family due to its high reproduction frequency."

Means of Introduction Outside the United States

From Bwanika et al. (2006):

"Four nonindigenous tilapiines (*Tilapia zillii* Gervais, *Oreochromis niloticus*, *Oreochromis leucostictus* Trewavas and *Tilapia rendalli* Boulenger) were also introduced at various points around Lake Victoria from 1953 onwards in response to reduced catch per unit effort (CPUE) of two native tilapiines (*Oreochromis esculentus* Graham and *Oreochromis variabilis* Boulenger) that were the main target of the local fishermen since the beginning of the Lake Victoria fisheries. By 1960, they had also been introduced in lakes Kyoga, Nabugabo, and later into other lakes within the region (Beauchamp 1958; Welcomme 1967, 1988)."

From Bwanika et al. (2007):

"Lake Wamala [Uganda] was stocked in 1956 with three tilapiine species (*O. niloticus*, *O. leucostictus and T. zillii*) but no Nile perch, and was opened to commercial fishing in 1960."

From Ogatu-Ohwayo (1989):

"[…] *Q. niloticus, Q.leucostictus,* and *T. melanopleura,* appear to have been introduced to supplement and diversify stocks of the native tilapiines which had declined due to overfishing."

From Froese and Pauly (2020):

"It [*O. leucostictus*] has since been spread throughout much of Tanzania as an accidental contaminant of farm strains of *Oreochromis niloticus* founded from Lake Victoria [Genner et al. 2018]."

Short Description

From Froese and Pauly (2020):

"Dorsal spines (total): 15 - 18; Dorsal soft rays (total): 10-13; Anal spines: 3-4; Anal soft rays: 9 - 11; Vertebrae: 27 - 29. Diagnosis: A small medium-sized tilapia, with a relatively deep, flattened body and small head and jaws [Genner et al. 2018]. Lower jaw not longer than 34% of the head, preorbital depth not more than 23.2%; teeth of jaws and pharynx very small, those of the lower pharyngeal restricted to the posterior part of the pad; 27-29 vertebrae [Trewavas 1983]. Scales on lateral line 28-30 [Bailey 1968; Trewavas 1983; van Oijen 1995], rarely 31 or 32 [Trewavas 1983]. Gill-rakers on lower part of first gill-arch 19-24 [Bailey 1968; van Oijen 1995]. Length/depth ratio of caudal peduncle 0.5-0.8 [van Oijen 1995]. Males are black with white spots on the flanks and fins; females are more olive coloured, with pale ventral regions, faint vertical barring and dark anal and tail fins [Greenwood 1966; Trewavas 1983; van Oijen 1995; Genner et al. 2018]. Lower lip often bluish-white; 8 to 12 dark vertical stripes sometimes visible on flanks [Greenwood 1966; Trewavas 1983; van Oijen 1995]. Dorsal, anal and caudal fins dark; soft dorsal, entire caudal and anal fins with well-defined bluish-white spots [Greenwood 1966; van Oijen 1995]. Genital papilla intensely white in both sexes [Trewavas 1983]. Ground color in breeding males changes to dark blue-black, whilst whitish spots on body and fins are intensified; eye outstanding with its bright amber iris crossed by a black bar [Greenwood 1966; Trewavas 1983; van Oijen 1995]."

Biology

From Froese and Pauly (2020):

"Occupies an inshore zone and is common in lagoons [Lowe-McConnell 1982]. Occasionally forms schools [Welcomme 1970; Trewavas 1983]. Is mainly diurnal [Trewavas 1983]. Can tolerate considerable deoxygenation [Welcomme 1965, 1988; Greenwood 1966; Trewavas 1983; Twongo 1995] and warm temperatures [Baensch and Riehl 1985], known to occur at 38.0 °C [Trewavas 1983]. Feeds on phytoplankton [Greenwood 1966; Trewavas 1983; Wohlfarth and Hulata 1983; Ochumba and Manyala 1992; Witte and de Winter 1995] and detritus [Ochumba and Manyala 1992; Witte and de Winter 1995; Hickley et al. 2002]. Ovophilic [Baensch and Riehl 1985], a maternal mouthbrooder [Thys van den Audenaerde 1964; Greenwood 1966; Witte and de Winter 1995; Genner et al. 2018]. Males dig simple pits in shallow water [Genner et al. 2018]. Strongly prone to precocious maturity; this makes it an undesirable aquaculture species [Genner et al. 2018]."

"Breeds over shallow muddy bottoms in sheltered inlets and in the papyrus fringe [Welcomme 1967]. Ripe males are found near the bottom over particular nesting areas [Welcomme 1970]. Males establish territory and make a nest by mouth-digging [Trewavas 1983], actively preventing invasion by other fishes [Welcomme 1970]. Nests made in shallow water, 15-300cm deep [Welcomme 1967; Trewavas 1983], 16-20cm in diameter and 1-4m apart, dug in coarse leaf-debris or on shallow muddy bottoms [Welcomme 1970; Trewavas 1983]. Brooding females from the lagoons are found in pools adjacent to the lagoons/nursery swamps [Welcomme 1970; Trewavas 1983]. Fry spent their early days in shallow, grassy [Welcomme 1965, 1970; Trewavas 1983] and deoxygenated swamps [Welcomme 1967], but move to deeper water as their length increases [Welcomme 1965, 1970]."

Human Uses

From Froese and Pauly (2020):

"Fisheries: ; aquaculture: experimental; aquarium: commercial"

"Caught in large numbers by small-meshed nets in shallow swampy areas, where it has become established [Genner et al. 2018]."

From Hickley et al. (2008):

"The initial suite of stocked species created a fishery that at one time sustained 104 fishing boats, albeit only 43 now. Fishing provides employment, and thus economic benefit, to fishers and their crew, families and associated traders. In 2004 & 2005, mean prices of fish were: *O. leucostictus*, 85 KSh kg-1 (US$ 1.10); *C. carpio*, 45 KSh kg-1 (US$ 0.60). The price of tilapia is relatively high because it is more in demand than carp as a table fish. This is because it is a known species, suits traditional cooking methods and has a flavour that is preferred by local consumers."

Diseases

No records of OIE-reportable diseases (OIE 2020) were found for *Oreochromis leucostictus*.

From Froese and Pauly (2020):

"Contracaecum Disease (larvae), Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Disease, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation 4, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation 2, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation 4, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation 7, Parasitic infestations (protozoa, worms, etc.)
Cichlidogyrus Infestation 10, Parasitic infestations (protozoa, worms, etc.)"

Poelen et al. (2014) lists *Polyacanthorhynchus kenyensis, Acanthogyrus tilapiae, Ophiovalipora minuta, Cichlidogyrus longicornis, Anacanthorus colombianus, Scutogyrus gravivaginus, Cichlidogyrus halli, Cichlidogyrus sclerosus, Cichlidogyrus tilapiae, Cichlidogyrus tubicirrus,* and *Gyrodactylus cichlidarum* as parasites of *Oreochromis leucostictus.*

From Aloo (2002):

"*Oreochromis leucostictus* and *Tilapia zillii* from lake Naivasha and the Oloidien Bay did not harbour any ectoparasites but both fish species hosted the larval stages of five helminths, namely: third stage larvae of *Contracaecum* sp., cystacanths of *Polyacanthorhynchus kenyensis*, cysticercoids of *Amirthalingamia* sp. and *Cyclustera* sp. and metacercariae of *Clinostomum* sp. The most prevalent and abundant parasites were *Contracaecum* sp. and *P. kenyensis*, but no seasonal variation in prevalence was observed in the two hosts […]. However, *O. leucostictus* was more heavily infected with *Contracaecum* sp. and *P. kenyensis* than *T. zillii*. The trematode *Clinostomum* sp. only infected *O. leucostictus*, whereas *Amirthalingamia* sp. only occurred in *T. zillii*. Cysticercoids of *Cyclustera* sp. were found in both *O. leucostictus* and *T. zillii* with a higher abundance in the latter […]. The parasites also infected a range of internal organs, i.e. *Contracaecum* was found free in the pericardial cavity of *O. leucostictus* but was encysted in *T. zillii*."

Threat to Humans

From Froese and Pauly (2020):

"Potential pest [Lever 1966]"

3 Impacts of Introductions

From Froese and Pauly (2020):

"Several countries report adverse ecological impact after introduction."

"When stocked along with Nile tilapia, probably will assist in filling all suitable niches and competitively excluding native species [Genner et al. 2018]."

"It has established in Lake Naivasha [Kenya] [Siddiqui 1977; Welcomme 1988] and hybridized with *O. spilurus niger* [Fryer and Iles 1972; Siddiqui 1977; Trewavas 1983; Welcomme 1988; 1978], which has now disappeared [Siddiqui 1977; Trewavas 1983]. Present in Kenyan waters of Lake Victoria [Welcomme 1988]. Has competed with the indigenous *O. variabilis* [Lever 1966]."

From Hickley et al. (2008):

"Impact: In L. Victoria, competition with indigenous tilapias."

O. leucostictus is listed as a prohibited species in Florida (FFWCC 2020).

4 History of Invasiveness

Oreochromis leucostictus has been stocked in Lake Victoria and adjacent lakes. There are some statements about impacts from those introductions, including the disappearance of a species after the introduction of and its hybridization with *O. leucostictus*. However there is no information available to the screener to determine the scientific defensibility of those statements.
O. leucostictus is a prohibited species in Florida. Therefore the History of Invasiveness is Data Deficient.

5 Global Distribution

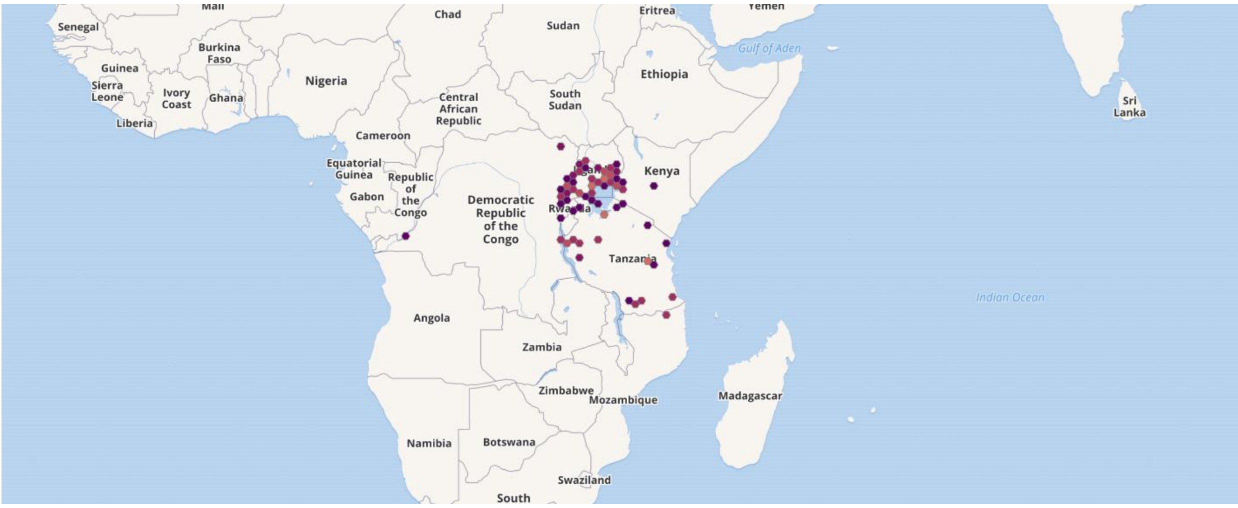


Figure 1. Known global distribution of *Oreochromis leucostictus*. Locations are in Democratic Republic of the Congo, Uganda, Rwanda, Burundi, Kenya, Tanzania, and Mozambique. Map from GBIF Secretariat (2020). The far western point in the Democratic Republic of the Congo was not used a source point due to lack of literature to support a population at this location.

GBIF Secretariat (2020) also included a record in Alabama, United States but it was collected from captivity and does not represent an established population, therefore, it was not used to select source points for the climate match. There was also a record in the United Kingdom that was the result of incorrect coordinates recorded for a specimen collected in Africa. This observation was not used to select source points for the climate match.

6 Distribution Within the United States

No records of *Oreochromis leucostictus* occurrences in the United States in the wild were found.

GBIF Secretariat (2020) also included a record in Alabama, United States but it was collected from captivity and does not represent an established population, therefore, it was not used to select source points for the climate match.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Oreochromis leucostictus* was low for the majority of the contiguous United States with patches of medium match the southeastern coast from North Carolina to Texas, as well as along the southern California coast and around Puget Sound. There were no areas of high match. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for the contiguous United States was 0.002, low (scores between 0.000 and 0.005, inclusive, are classified as low). Florida and Texas had individual climate scores of medium, while the rest of the States had low individual climate scores.

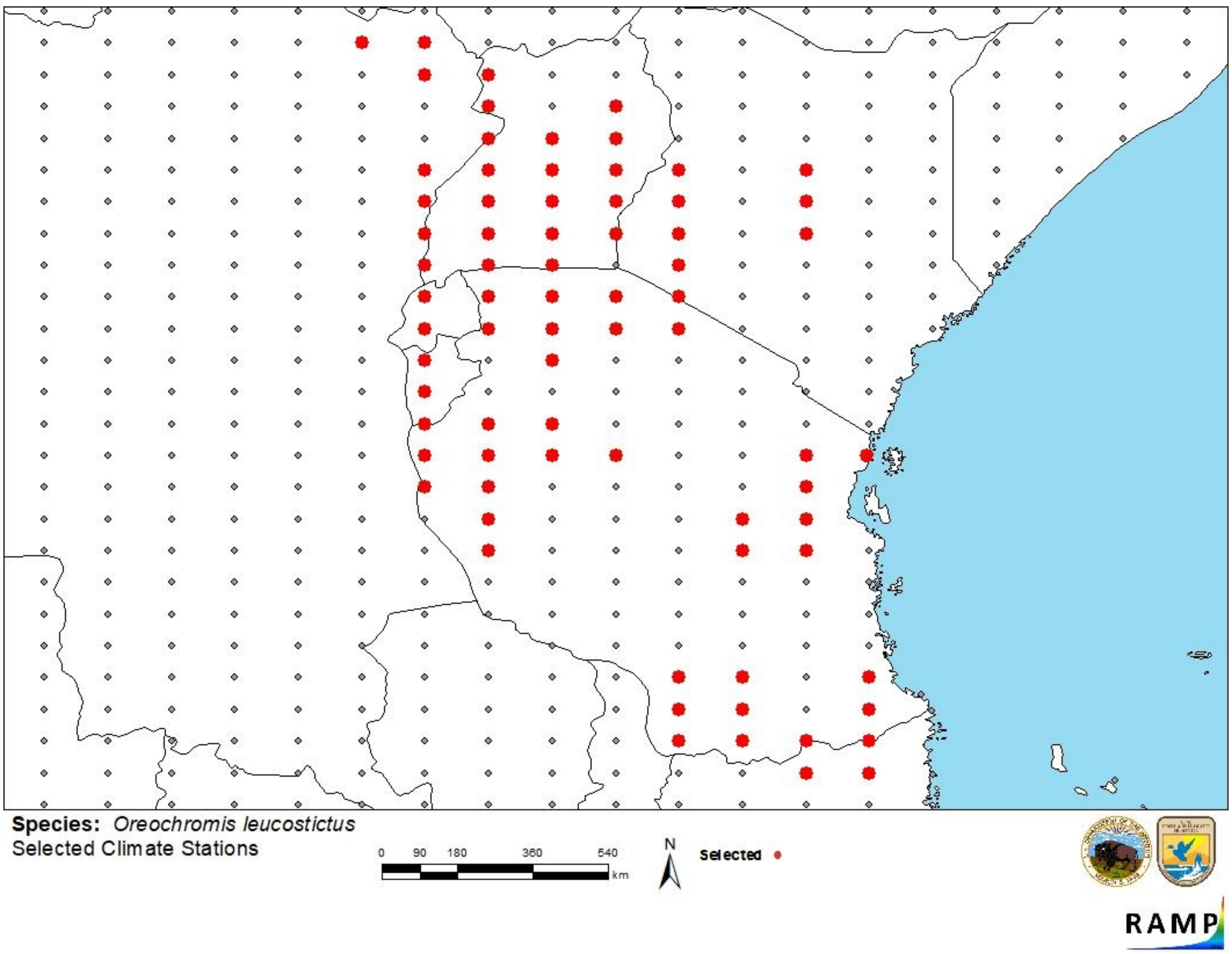


Figure 2. RAMP (Sanders et al. 2018) source map showing weather stations in eastern Africa selected as source locations (red; Democratic Republic of the Congo, Uganda, Rwanda, Burundi, Kenya, Tanzania, Mozambique) and non-source locations (gray) for *Oreochromis leucostictus* climate matching. Source locations from GBIF Secretariat (2020). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

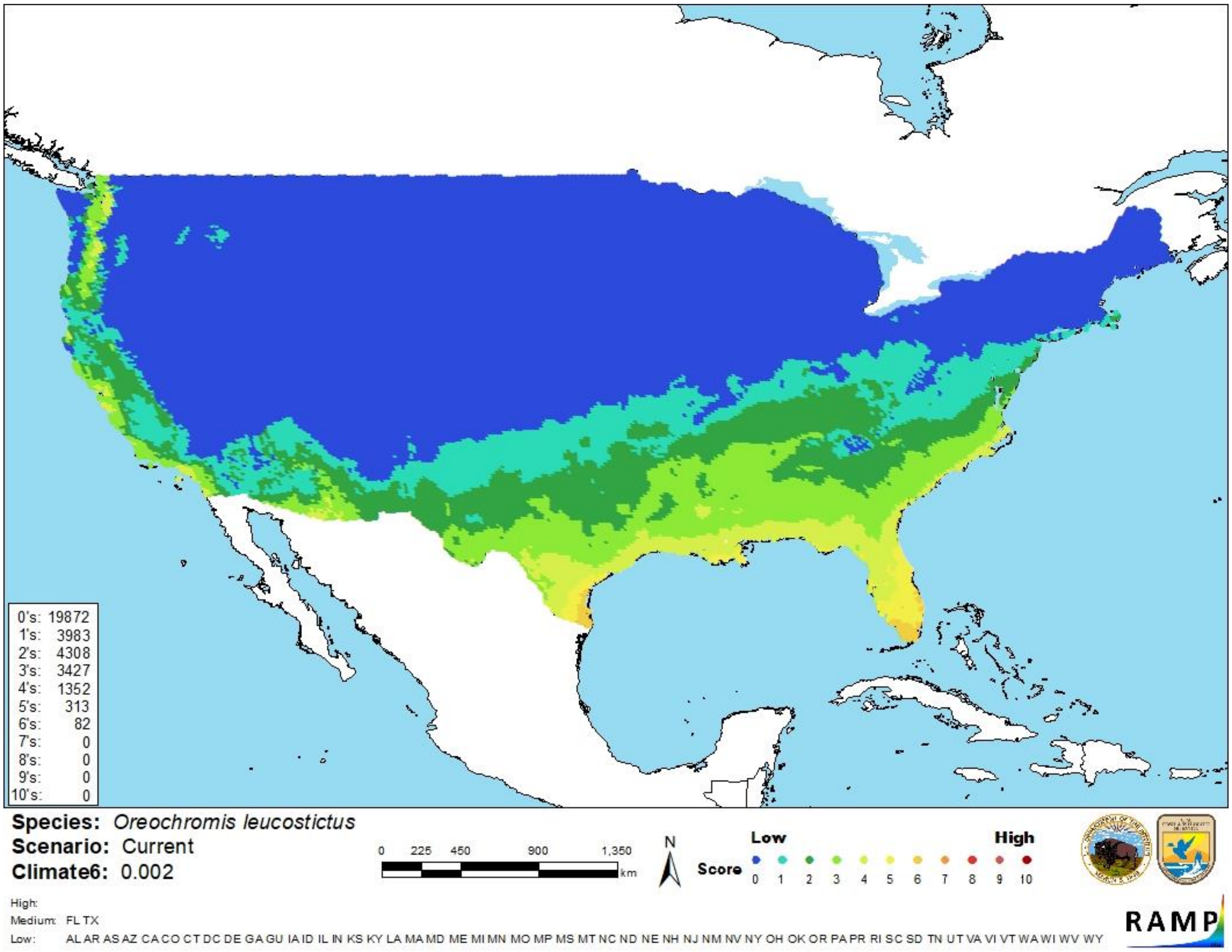


Figure 3. Map of RAMP (Sanders et al. 2018) climate matches for *Oreochromis leucostictus* in the contiguous United States based on source locations reported by GBIF Secretariat (2020). Counts of climate match scores are tabulated on the left. 0/Blue = Lowest match, 10/Red = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: (Count of target points with climate scores 6-10)/ (Count of all target points)	Overall Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

8 Certainty of Assessment

The certainty of this assessment is low. There is limited scientific literature available documenting the impacts of the introduction of *Oreochromis leucosticuts* to surrounding lakes.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Blue spotted tilapia, *Oreochromis leucostictus* is a fish native to the Democratic Republic of the Congo and Uganda in Africa. *O. leucostictus* is listed as a prohibited species in Florida. *O. leucostictus* is consumed as a food fish for humans and has been widely stocked in areas surrounding the native range to create more fisheries. Those stocking events to meet fishery management goals have resulted in established populations outside of its native range. Statements were found that *O. leucosticus* competed and hybridized with native species, possibly resulting in the elimination of a native species, and had adverse ecological impacts, but no information was available to support these statements. Therefore, history of invasiveness is data deficient. The climate match analysis resulted in a low match for the contiguous United States, with areas of medium match mainly along the southeastern Atlantic and Gulf Coasts. The certainty of this assessment is low due to a lack of information. The overall risk assessment category in uncertain.

Assessment Elements

- **History of Invasiveness (Sec. 4): Data Deficient**
- **Overall Climate Match Category (Sec. 7): Low**
- **Certainty of Assessment (Sec. 8): Low**
- **Remarks/Important additional information:** No additional information
- **Overall Risk Assessment Category: Uncertain**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 11.

Aloo PA. 2002. A comparative study of helminth parasites from the fish *Tilapia zillii* and *Oreochromis leucostictus* in Lake Naivasha and Oloidien Bay, Kenya. Journal of Helminthology 76:95–102.

Bwanika GN, Chapman LJ, Kizito K, Balirwa J. 2006. Cascading effects of introduced Nile perch (*Lates niloticus)* on the foraging ecology of Nile tilapia (*Oreochromis niloticus*). Ecology of Freshwater Fish 15:470–481.

Bwanika GN, Murie DJ, Chapman LJ. 2007. Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in lakes Nabugabo and Wamala, Uganda. Hydrobiologia 589:287–301.

Eschmeyer WN, Fricke R, van der Laan R, editors. 2018. Catalog of fishes: genera, species, references. California Academy of Science. Available: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (July 2018).

[FAO] Fisheries and Agriculture Organization of the United Nations. 2018. Database on introductions of aquatic species. Rome: FAO. Available: http://www.fao.org/fishery/introsp/search/en (July 2018).

[FFWCC] Florida Fish and Wildlife Conservation Commission. 2020. Tallahassee, Florida: Prohibited species list. Florida Fish and Wildlife Conservation Commission. Available: http://myfwc.com/wildlifehabitats/nonnatives/regulations/prohibited/ (May 2020).

Froese R, Pauly D, editors. 2020. *Oreochromis leucostictus* Trewavas, 1933. FishBase. Available: http://www.fishbase.org/summary/Oreochromis-leucostictus.html. (May 2020).

GBIF Secretariat. 2020. GBIF backbone taxonomy: *Oreochromis leucostictus* (Trewavas, 1933). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/2372381 (May 2020).

Hickely P, Muchiri M, Britton R, Boar R. 2008. Economic gain versus ecological damage from the introduction of non-native freshwater fish: Case studies from Kenya. The Open Fish Science Journal 1:36–46.

[ITIS] Integrated Taxonomic Information System. 2018. *Oreochromis leucostictus* (Trewavas, 1933). Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=649530 (July 2018).

Ogatu-Ohwayo R. 1989. The purpose, cost and benefits of fish introductions: with specific reference to the Great Lakes of Africa. Uganda Freshwater Fisheries Research Organization 1–27.

[OIE] World Organisation for Animal Health. 2020. OIE-listed diseases, infections and infestations in force in 2020. Available: http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2020/ (May 2020).

Poelen JH, Simons JD, Mungall CJ. 2014. Global Biotic Interactions: an open infrastructure to share and analyze species-interaction datasets. Ecological Informatics 24:148–159.

Sanders S, Castiglione C, Hoff M. 2018. Risk Assessment Mapping Program: RAMP. Version 3.1. U.S. Fish and Wildlife Service.

11 Literature Cited in Quoted Material

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Baensch HA, Riehl R. 1985. Aquarien atlas. Band 2. Melle, Germany: Mergus, Verlag für Natur- und Heimtierkunde GmbH.

Bailey RG. 1968. Fishes of the genus *Tilapia* (Cichlidae) in Tanzania, with a key for their identification. East African Agricultural and Forestry Journal 34:194–202.

Balirwa JS. 1979. A contribution to the study of the food of six cyprinid fishes in three areas of the Lake Victoria Basin, East Africa. Hydrobiologia 66(1):65–72.

Beadle LC. 1981. The inland waters of tropical Africa. An introduction to tropical limnology. Second edition. London: Longman Group Limited.

Beauchamp RSA. 1958. Utilizing the natural resources of Lake Victoria for the benefit of fisheries and Agriculture. Nature 181:1634–1636.

Crespi V, Ardizzone GD. 1995. Fishery resources and some economic aspects of four fishing villages on lakes George and Edward in the Queen Elizabeth National Park, Uganda. African Journal of Tropical Hydrobiology and Fisheries 6:11–20.

David L, Poll M. 1937. Contribution à la faune ichthyologique du Congo Belge: collections du Dr. H. Schouteden (1924–1926) et d'autres récolteurs. Annales du Musée royal du Congo Belge, Tervuren, Belgique. Série in 8o, Sciences zoologiques 3(5):189–294.

De Vos L, Snoeks J, Thys van den Audenaerde DFE. 2001. An annotated checklist of the fishes of Rwanda (east central Africa), with historical data on introductions of commercially important species. Journal of East African Natural History 90:41–68.

Decru E. 2015. The ichthyofauna in the Central Congo basin: diversity and distribution in the north-eastern tributaries. Leuven, Belgium: KULeuven, Faculty of Science.

Eccles DH. 1992. FAO species identification sheets for fishery purposes. Field guide to the freshwater fishes of Tanzania. Prepared and published with the support of the United Nations Development Programme, Project URT/87/016. Rome: FAO.

Fryer G, Iles TD. 1972. The cichlid fishes of the Great Lakes of Africa: their biology and evolution. Edinburg, U.K.: Oliver and Boyd.

Genner MJ, Turner GF, Ngatunga BP. 2018. A guide to the tilapia fishes of Tanzania. Martin J. Genner, George F. Turner and Benjamin P. Ngatunga.

Greenwood PH. 1966. The fishes of Uganda. Kampala: The Uganda Society.

Hepher B, Pruginin Y. 1982. Tilapia culture in ponds under controlled conditions. Pages 185–203 in Pullin RSV, Lowe-McConnell RH, editors. The biology and culture of tilapias. ICLARM Conference Proceedings 7.

Hickley P, Bailey R, Harper DM, Kundu R, Muchiri M, North R, Taylor A. 2002. The status and future of the Lake Naivasha fishery, Kenya. Hydrobiologia 488:181–190.

Hickley P, North R, Muchiri SM, Harper DM. 1994. The diet of largemouth bass, *Micropterus salmoides*, in Lake Naivasha, Kenya. Journal of Fish Biology 44(4):607–619.

Kanyike ES. 1990. The Uganda waters of Lake Victoria. FAO Fisheries Report 430:16–17.

Lever C. 1996. Naturalized fishes of the world. California: Academic Press.

Lowe RH. 1957. Observations on the diagnosis and biology of *Tilapia leucosticta* Trewavas in East Africa. Revue de Zoologie et de Botanique Africaines 55(3-4):353–373.

Lowe RH. 1958. Observations on the biology of *Tilapia nilotica* Linné in East African waters. Revue de Zoologie et de Botanique Africaines 57(1-2):129–170.

Lowe-McConnell RH. 1982. Tilapias in fish communities. Pages 83–113 in Pullin RVS, Lowe-McConnell RH, editors. The biology and culture of tilapias. ICLARM Conference Proceedings 7.

Moreau J, Christensen V, Pauly D. 1993. A trophic ecosystem model of Lake George, Uganda. Pages 124–129 in Pauly D, Christensen V, editors. Trophic models of aquatic ecosystems. ICLARM Conference Proceedings 26.

Muchiri SM, Hart PJB, Harper DM. 1995. The persistence of introduced tilapia species in Lake Naivasha, Kenya, in the face of environmental variability and fishing pressure. Pages 299–319 in Pitcher TJ, Hart PJB, editors. The impact of species changes in African Lakes. Chapman & Hall Fish & Fisheries Series 18.

Mwanja W, Kaufman L. 1995. A note on recent advances in the genetic characterization of Tilapia stocks in Lake Victoria Region. African Journal of Tropical Hydrobiology and Fisheries 6:51–53.

Noakes DGL, Balon EK. 1982. Life histories of tilapias: an evolutionary perspective. Pages 61–82 in Pullin RSV, Lowe-McConnell RH, editors. The biology and culture of tilapias. ICLARM Conference Proceedings 7.

Ochumba PBO, Manyala JO. 1992. Distribution of fishes along the Sondu-Miriu River of Lake Victoria, Kenya with special reference to upstream migration, biology and yield. Aquaculture and Fisheries Management 23:701–719.

Ogutu-Ohwayo R. 1985. The effect of predation by nile perch, *Lates niloticus* (Linné) introduced into Lake Kyoga (Uganda) in relation to the fisheries of Lake Kyoga and Lake Victoria. FAO Fisheries Report 335:18–41.

Okeyo DO. 2003. Taxonomy, common names and distribution of fish in the eastern arm of the Rift Valley drainage, Kenya. Pages 250–266 in Palomares MLD, Samb B, Diouf T, Vakily JM, Pauly D, editors. Fish biodiversity: local studies as basis for global inferences. ACP-EU Fisheries Research Report 14.

Poll M. 1939. Exploration du Parc National Albert. Mission G.F. de Witte (1933–1935). Fascicule 24. Poissons. Bruxelles, Belgium: Institut des Parcs Nationaux du Congo belge.

Poll M, Damas H. 1939. Exploration du Parc National Albert. Mission H. Damas (1935–1936). Fascicule 6. Poissons. Bruxelles, Belgium: Institut des Parcs Nationaux du Congo belge.

Robotham PWJ. 1990. Trophic niche overlap of the fry and juveniles of *Oreochromis leucostictus* (Teleostei, Cichlidae) in the littoral zone of a tropical lake (L. Naivasha, Kenya). Revue d'Hydrobiologie Tropicale 23(3):209–218.

Schofield PJ, Chapman LJ. 1999. Interactions between Nile perch, *Lates niloticus*, and other fishes in Lake Nabugabo, Uganda. Environmental Biology of Fishes 55:343–358.

Seegers L, De Vos L, Okeyo DO. 2003. Annotated checklist of the freshwater fishes of Kenya (excluding the lacustrine haplochromines from Lake Victoria). Journal of East African Natural History 92:11–47.

Shechonge A, Ngatunga BP, Bradbeer SJ, Day JJ, Freer JJ, Ford AGP, Kihedu J, Richmond T, Mzighani S, Smith AM, Sweke EA, Tamatamah R, Tyers AM, Turner GF, Genner MJ. 2018. Widespread colonisation of Tanzanian catchments by introduced *Oreochromis* tilapia fishes: the legacy from decades of deliberate introduction. Hydrobiologia 832:235–253.

Siddiqui AQ. 1977. Reproductive biology, length-weight relationship and relative condition of *Tilapia leucosticta* (Trewavas) in Lake Naivasha, Kenya. Journal of Fish Biology 10(3):251–260.

Thys van den Audenaerde DFE. 1963. La distribution géographique des *Tilapia* au Congo. Bull. Séances Acad. R. Sci. Outre-Mer 9(3):570-605.

Thys van den Audenaerde DFE. 1964. Révision systématique des espèces congolaises du genre Tilapia (Pisces, Cichlidae). Annales du Musée Royal de l'Afrique Centrale: Sciences Zoologiques 124:1–155.

Trewavas E. 1933. Scientific results of the Cambridge Expedition to the East African Lakes, 1930-1. 11. The cichlid fishes. The Journal of the Linnean Society of London Zoology 38:309–341.

Trewavas E. 1983. Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. London: British Museum of Natural History.

Twongo T. 1995. Impact of fish species introductions on the tilapias of Lakes Victoria and Kyoga. Pages 45–57 in Pitcher TJ, Hart PJB, editors. The impact of species changes in African Lakes. Chapman and Hall, Fish and Fisheries Series 18.

van Oijen MJP. 1995. Appendix I. Key to Lake Victoria fishes other than haplochromine cichlids. Pages 209–300 in Witte F, van Densen WLT, editors. Fish stocks and fisheries of Lake Victoria. A handbook for field observations. Dyfed, Great Britain: Samara Publishing.

Verbeke J. 1959. Le régime alimentaire des poissons des lacs Édouard et Albert (Congo Belge). Rés. Sci. Expl. Hydrobiol. Lacs Kivu, Édouard et Albert (1952–1954) 3(3):1–66.

Welcomme RL. 1965. Further observations on the biology of the introduced *Tilapia* species. East African Freshwater Fisheries Research Organization 1964:18–31.

Welcomme RL. 1967. Observations on the biology of the introduced species of *Tilapia* in Lake Victoria. Revue de zoologie et de botanique africaines 76(3–4):249–279.

Welcomme RL. 1970. Studies on the effects of abnormally high water levels on the ecology of fish in certain shallow regions of Lake Victoria. Journal of Zoology London 160:405–436.

Welcomme RL. 1988. International introductions of inland aquatic species. FAO Fisheries Technical Paper 294:1–318.

Witte F, de Winter W. 1995. Appendix II. Biology of the major fish species of Lake Victoria. Pages 301–320 in Witte F, Van Densen WLT, editors. Fish stocks and fisheries of Lake Victoria. A handbook for field observations. Dyfed, Great Britain: Samara Publishing.

Wohlfarth GW, Hulata G. 1983. Applied genetics of tilapias. 2nd edition. ICLARM Student Review 6.

van Oijen MJP. 1995. Appendix I. Key to Lake Victoria fishes other than haplochromine cichlids. Pages 209–300 in Witte F, van Densen WLT, editors. Fish stocks and fisheries of Lake Victoria. A handbook for field observations. Dyfed, Great Britain: Samara Publishing.