CHARACTERIZATION OF TRIPLOID GRASS CARP STOCKINGS IN PRIVATE WATERS OF TEXAS

by

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure **Page**

ABSTRACT

Grass Carp *Ctenopharyngodon idella* is used worldwide as a biological control of nuisance aquatic vegetation. Use of triploid Grass Carp in Texas was legalized for stocking on private lands in 1992. Since 1992, landowners seeking to stock triploid Grass Carp must complete a Texas Parks and Wildlife Department (TPWD) permit application, which requires the number of Grass Carp requested, estimated surface area, percent vegetation coverage, and other information on the location and characteristics of the receiving water body. Once applications are received by TPWD, specifics of the application are entered into a database before being approved or denied by TPWD personnel. Purpose of this study was to summarize and characterize the number of permits, number of triploid Grass Carp requested, receiving water body characteristics, and estimated costs in stocking triploid Grass Carp between 1992 and 2020. A total of 30,387 permit applications were submitted, requesting 818,667 triploid Grass Carp of which 793,020 were approved by TPWD. Mean number (± 1 SD) of permit applications per year was 1,048 (± 166), and mean number of triploid Grass Carp requested per year was 28,229 (± 7,881). Trends in permit applications and number of triploid Grass Carp requested were similar between 1992 and 2020. Greater number of requests were for first time, introductory stockings than repeat, supplemental stockings and were from east Texas ecoregions than in central and west Texas ecoregions. Majority of the receiving water bodies were <2.0 ha with >50% submergent vegetative coverage. About 4% of the applications were denied. Estimated cost of stocking ranged between $200 and $400 per

ha. Results of this study inform landowners on the practice of triploid Grass Carp as a biological control of nuisance aquatic vegetation but also highlights gaps in information, such as efficacy in controlling aquatic vegetation and the number of triploid Grass Carp stocked, that could benefit TPWD and other natural resource agencies that continue to regulate the stocking of triploid Grass Carp.

I. CHARACTERIZATION OF TRIPLOID GRASS CARP STOCKINGS IN PRIVATE WATERS OF TEXAS

Introduction

The social consciousness shifts attributed to Rachel Carson's Silent Spring (1962) led to widespread ecological and environmental movements calling for the minimization of chemicals as a control of pests, such as insects detrimental to agriculture and various types of invasive and native vegetation (Carson 2002, Hazlett 2003, Culver et al. 2012). Biological control of terrestrial and aquatic organisms has since become a popular focus regarding ecological persistence via deterrence of pesticide and herbicide use and as alternative to costly and labor-intensive mechanical controls (Tu et al. 2001, Williams and Hecky 2005, Adams 2010, Stallings et al. 2015). The large-scale construction of over 75,000 dams on river systems throughout the USA in the mid-20th century and the continued construction of more than 2.5 million privately-owned ponds for water supply needs, flood control, irrigation, farm use and livestock, and sport fisheries for recreation among other uses has led to large scale water resource managerial needs with a call for sustainable practices (Graf 1999, McMurry 2020). The collective problem is that dammed water bodies are susceptible to eutrophication processes, where inflowing sediments and nutrients accumulate and facilitate aquatic vegetation growth (Williams and Hecky 2005, Beckingham et al. 2019, McMurry 2020). Large coverage of aquatic vegetation, native and non-native species, is referred to as nuisance vegetation when it impedes original function of the water body (Williams and Hecky 2005, McMurry 2020). Biological control of nuisance vegetation is a cheaper and non-toxic alternative to the use of chemicals (Blackburn et al. 1971, Andres and Bennet 1975).

The use of biological controls is not universally accepted as an environmental-

friendly alternative to chemical use (Pimental 1980). Several species, such as Grass Carp *Ctenopharyngodon idella*, Mozambique Tilapia *Oreochromis mossambicus,* Alligator Weed Flea Beetle *Agasicles hygrophila*, Water Hyacinth Weevil *Neochetina eichhorniae*, Water Lettuce Weevil *Neohydronomus affinis,* and Salvinia Weevils *Cyrtobagous salviniae*, are used in the USA as biological controls (Mitzner 2011, Russell et al. 2012, Chilton 2018). However, short-term and long-term effectiveness is unknown for many of these biological controls (Quimby et al. 2002, Dibble and Kovalenko 2009, Stallings et al. 2015) along with their invasiveness potential (i.e., dispersion outside the point of introduction; Pimental 1980, USFWS 2018) or foraging specificity (i.e., the ability to switch or not to other aquatic vegetation besides the nuisance aquatic vegetation; Pimental 1980, Stallings et al. 2015, Chilton 2018). Sustainable use of biological controls will require additional information before claiming that biological controls are a safer alternative to chemical use.

Grass Carp is a member of the Cyprinidae family native to the Amur River and associated rivers and lakes within the Pacific Ocean basin of eastern Russia and China (Stevenson 1965, Bailey and Boyd 1972, Shireman and Smith 1983). Its consumption of aquatic vegetation, up to its body weight per day (Wiley et al. 1986, Leslie et al. 1987, Cassani 1996), generalist feeding behavior (Edwards 1974, Colle et al. 1978, Van Dyke et al. 1984), relatively long life span (Kirk and Socha 2003), and survivability in most freshwater systems (Sutton 1977, Shireman and Smith 1983, Cassani 1996) enable the use of Grass Carp as a popular biological control for aquatic vegetation, where it has been introduced to over 80 countries worldwide (FishBase 2004, USFWS 2018). Grass Carp was first introduced to USA in 1963 by the U.S. Fish and Wildlife Service (USFWS)

(Cross 1969, Guillory and Gasaway 1978) as a biological alternative to herbicides for control of nuisance aquatic vegetation (Mitchell and Kelly 2006, USFWS 2018). In 1974, commercial production of Grass Carp began within the USA (Cassani 1996, Nico et al. 2018, USFWS 2018). That same year, reproducing populations of Grass Carp were documented within the Mississippi River basin and other basins within southeastern USA, attributed to escapement of Grass Carp from areas where initially stocked, beginning a long history of regulations designed to minimize unintentional spread (Baily and Boyd 1972, Conner et al. 1980, Brown and Coon 1991). To lessen reproducing Grass Carp populations, sterile triploid Grass Carp were developed in 1983 leading to increased use where previously banned or highly regulated (Malone 1984, Cassani and Canton 1986, Leslie et al. 1987, Cassani 1996). In 1985, the USFWS developed a testing and verification process to certify Grass Carp as sterile for commercial production shipments (Griffin 1991, Mitchell and Kelly 2006). Grass Carp are reported in 45 US states with eight US states, including Texas, having established reproducing populations (Elder and Murphy 1997, USFWS 2018).

In Texas, stocking of Grass Carp is regulated by Texas Parks and Wildlife Department (TPWD). In 1980, Grass Carp were initially prohibited in Texas aside from experimental stockings to Lake Conroe in the early 1980s (Trimm et al. 1989, Elder and Murphy 1997). In 1992, TPWD developed a permitting system to allow stocking of triploid Grass Carp in private and public waters but with several conditions (Maceina et al. 1991, Chilton and Poarch 1997, Chilton 2018). Conditions were designed to reduce the potential for negative ecological effects, such as ensuring that escapement risk is low and prohibiting stocking near ecologically sensitive river reaches (Cassani 1996, Webb et

al. 2000, MICRA 2015). An example of an ecologically sensitive river reach is the upper San Marcos River (Hays County Texas) with the federally-listed Fountain Darter *Etheostoma fonticola* that associates with aquatic vegetation (Edwards and Bonner, in press). Landowners seeking to stock triploid Grass Carp in private waters require a stocking permit issued through TPWD. The permitting process includes an application to be completed by landowners (see triploid Grass Carp information and permitting; tpwd.texas.gov). Landowners are asked to provide specific locations of their water body, if the water body has an escapement barrier or not, and estimates of water body size, vegetation coverage, and vegetation type. Applications are reviewed by TPWD management biologists, and in some cases, a site visit is necessary before a permit is authorized. Stocking rates are determined based on percent vegetative coverage: 12 fish per ha if the water body has <50% vegetative coverage and 25 fish per ha if >50% vegetative coverage. Supplement stockings are recommended every 5 to 7 years for long term effectiveness.

Since the legalization of triploid Grass Carp in Texas, information is lacking on how many and where triploid Grass Carp have been stocked in private waters of Texas. Additionally, it is unknown if the use of triploid Grass Carp as a biological control is increasing or decreasing among Texas landowners, the average cost of stocking triploid Grass Carp, and pond characteristics of those seeking to stock. A review of triploid Grass Carp stocking practices in Texas would inform private landowners and state regulatory agencies as they consider the value of triploid Grass Carp as biological controls of nuisance vegetation. Unfortunately, stocking records of triploid Grass Carp are not publicly assessable. However, information contained within TPWD applications can

provide estimates, with some limitations, on the practice of triploid Grass Carp stocking among private landowners.

Purpose of this study is to conduct a review of triploid Grass Carp permit applications for private waters submitted to TPWD between years 1992 and 2020. Study objectives are to 1) summarize the numbers of permit applications and triploid Grass Carp requested in Texas since 1992, 2) characterize surface area, barrier and spillway, vegetation type, discharge location, water source, and percent vegetation of receiving water bodies, 3) calculate the number of application denials and reasons for denials, and 4) estimate expenditures on triploid Grass Carp stocking, including costs to landowners and revenue generated from application fees, surcharges, and costs per fish, assuming all triploid Grass Carp were purchased as permitted. Study objectives were developed to assess if the number of permit applications and number of triploid Grass Carp requested are increasing or decreasing through time and if the number of permit applications and number of triploid Grass Carp requested are equally distributed throughout Texas or not, based on water availability or by human population size. Predications are that greater number of permits and number of triploid Grass Carp requested will be found in more humid regions of the state, using annual precipitation as a surrogate for water availability, and that more populated areas in Texas will submit more permit applications and request more triploid Grass Carp than less populated areas of Texas.

Methods

Information was taken from a TPWD database with records spanning the period between 1992 and 2020. Personal information (i.e., name, street address) were excluded

from the database to protect landowner privacy. Column titles consisted of the following: permit identification number, applicant identification number, water body identification number, TPWD Inland Fisheries district, Texas county, date application received, date permit was issued, number of triploid Grass Carp requested, water surface area (ha), vegetation surface area, vegetation type, water supply type, discharge location, presence of a barrier or spillway, and reason for permit denial (Table 1). Applicants were asked to estimate water surface area, vegetation surface area, and vegetation type. Their responses were accepted as provided; however, several landowners did not provide estimates of vegetation surface areas and vegetation type. Therefore, the database contained missing data. Number of triploid Grass Carp requested by the landowner was potentially modified by TPWD personnel to reflect the number permitted to stock, except for permit applications that were denied.

Number of permit applications and number of triploid Grass Carp requested were summarized among years. Cumulative frequency plots were generated to assess if number of permit applications and number of triploid Grass Carp requested were increasing, decreasing, or remaining consistent through time. Number of permit applications and number of triploid Grass Carp requested were summarized by ecoregions of Texas. Justifications for using Texas ecoregions include that the Texas ecoregions (Gould et al. 1960, modified by TPWD 2021) provided sufficient resolution to assess spatial patterns in permit applications, and data on precipitation amounts and human population size were readily available for each ecoregion. Ecoregions were not delineated in the database and, therefore, identified based on Texas county listed by the landowner. Once ecoregions were identified for each application, applications were

sorted by ecoregion, and numbers of permit applications and triploid Grass Carp requested were calculated for each ecoregion. Numbers of permit applications were correlated (Pearson Correlation, Neter et al. 1996; $\alpha = 0.05$) with annual precipitation of the ecoregion (Bailey 1995) and with human population size per county within each ecoregion (worldpopulationreview.com, accessed on 5 July 2021). Summaries of water body characteristics and numbers of denials, which were recorded beginning in 2005, were generated for the complete dataset and not by ecoregions.

Expenditures related to stocking were estimated for costs in 2020, using contemporary TPWD application fees and fish costs. In 2020, application processing fee is $16.00, permit fee per triploid Grass Carp is $2.00, and fish cost is $14.00 (per local vendor: Johnson Lake Management Service, San Marcos, Texas). Costs generated were estimated statewide and based on accepted permit applications. A caveat with estimating expenditures is that the number of triploid Grass Carp permitted are likely an overestimate of triploid Grass Carp that were purchased and stocked (Steinkoenig 1993). Landowners are not under obligations to stock the numbers as permitted and may opt to stock fewer numbers.

Results

A total of 30,387 permit applications was submitted to TPWD, requesting 818,667 triploid Grass Carp between 1992 and 2020. Application for introductory stocking was 71% with 29% of the applications requesting supplemental stocking of triploid Grass Carp. Mean number (± 1 SD) of permit applications per year was 1,048 (± 166; range: 701 – 1,468), and mean number of triploid Grass Carp requested per year was

28,229 (± 7,881; range: 13,897 – 44,808). Mean number of triploid Grass Carp requested per permit was 27 (± 92; range: 1 – 5,560; Figure 1). Trends in cumulative frequency through time indicated the number of permit applications and number of triploid Grass Carp requested were similar across years with no indications of the number of permit applications decreasing through time (Figure 2). Numbers of permit applications were greater among east Texas ecoregions than in central and west Texas ecoregions (Figure 3). Likewise, numbers of triploid Grass Carp requested were greater among east Texas ecoregions than in central and west Texas (Figure 4). Number of permit applications per ecoregion was positively correlated with average annual precipitation ($r^2 = 0.60$; $P < 0.01$) but not with human population ($r^2 = 0.21$; $P = 0.11$) (Figure 5).

Applicants varied in completeness for estimating water surface area (99.9% responding), barrier type or spillway (99.9%), vegetation type (61%), water discharge (53%), water source (51%), and percent vegetation coverage (47%). Mean water surface area (± 1 SD) was 2.0 ha (± 6.4), ranging in surface area from 0.004 to 158 ha (Figure 6). Water bodies consisted of containing barriers (26%) and spillways (61%). Vegetation types were submergent (45%), emergent (40%), filamentous algae (10%), and floating (5%). Water discharges were pasture (58%), dry creek (23%), ditch (11%), flowing creek (6%) and culvert (3%). Water sources were surface runoff (74%), spring fed (20%), well (4%), and flowing creek (2%). Percent vegetation coverages were >50% (86%) and <50% (14%).

Between 2005 and 2020, 3.5% of the permit applications were denied. Primary justifications for denials were “no response from applicant” (44% of the denials), “high risk that large numbers of Grass Carp will escape into public waters” (31%), and “Grass

Carp are not effective on the species of plant in the water body" (16%). Additional justifications were "information obtained during on-site inspection was inconsistent with information provided on application" (3.2%), "pond is in an ecologically sensitive area" (3.1%), "pond emptied directly into a restricted public water body" (2.4%), and "pond was stocked at the maximum allowable number of Grass Carp within the last five years" (1.2%). Subtracting the number of denied permits since 2005 (N = 589), 29,798 applications and 793,020 triploid Grass Carp were approved and permitted for stocking.

Estimated total expenditures of stocking triploid Grass Carp from 1992 through 2020, prorated to 2020 costs and assuming all permitted fish were purchased and stocked, was $13.2 million ($454,000 annually). Estimated revenue for permit fees was $477,000 ($16,400 annually) for application processing and $1.6 million ($54,700 annually) for the surcharge on each triploid Grass Carp permitted. Estimated revenue for the purchase of triploid Grass Carp was $11.1 million ($383,000 annually). Estimated permit cost to landowners, including permit fees, surcharge, and cost of triploid Grass Carp, ranged from $32.00 (N of requested fish =1) to $89,000 (N = 5,560). Mean costs, based on the mean number of triploid Grass Carp requested (N = 27), was $448. With stocking densities variable depending on the percent vegetation coverage, estimated costs per ha with <50% vegetative coverage was $208 (N of fish = 12), and estimated costs per ha with >50% vegetative coverage was $416 (N of fish = 25).

Discussion

Numbers of permit applications and numbers of requested triploid Grass Carp by private landowners have remained consistent through time in Texas. The typical permit

application is from east Texas ecoregions with greater amounts of precipitation but not necessarily among highly populated ecoregions. The typical water body is smaller ponds (< 2.0 ha) with submergent and emergent vegetation with >50% in surface area coverage, and the typical number of triploid Grass Carp stocked was ≤10. Majority of permit applications are for introductory stocking. It is currently unknown if requests for supplement stocking represent an estimation of triploid Grass Carp efficiency and satisfaction or not since justifications for supplemental stocking requests are not part of the permit application.

An estimated 7 million triploid Grass Carp were distributed among U.S. states between 1985 and 2005 (Mitchell and Kelly 2006), and 5 million triploid Grass Carp were certified by USFWS for distribution between 2002 and 2012 (MICRA 2015). Texas and Florida are among the top U.S. states requesting certified triploid Grass Carp. Mean numbers of certified triploid Grass Carp purchased annually were roughly 70,000 in Texas and 110,000 in Florida between 2002 and 2012 (MICRA 2015). This estimate of 70,000 triploid Grass Carp purchased annually in Texas is greater than the mean number (± 1 SD) of triploid Grass Carp requested per year reported herein (28,229 ± 7,881) between 1992 and 2020. Discrepancies in the number reported purchased and the number of requested via TPWD permitting process could be attributed to purchase of triploid Grass Carp for stocking in public waters or overestimates of the number of triploid Grass Carp purchased for stocking in Texas. Nine other states requested roughly 45,000 and 20,000 certified triploid Grass Carp during the same 10-year period with all remaining states requesting <5,000 triploid Grass Carp (MICRA 2015). However, not all states require Grass Carp to be USFWS-certified as triploid Grass Carp or even require for

Grass Carp to be triploid (Perrings et al. 2002, MICRA 2015). Therefore, contemporary estimates of Grass Carp stocked per state are difficult to ascertain. Likewise, it is difficult to assess increasing or decreasing trends in triploid Grass Carp stocking nationwide. In 1993, the state of Virginia had 9,000 triploid Grass Carp stocked on average annually (Steinkoenig 1993), whereas in 2012, the annual average stocking rate jumped to 20,000 (MICRA 2015). Why the number of permit applications and the number of triploid Grass Carp requested in Texas have remained consistent through time, whereas at least one other state has increasing requests, is not clear at this time.

Fewer permit requests and numbers of triploid Grass Carp requested in west Texas ecoregions than in east Texas ecoregions is similar to the nationwide pattern of more arid and western U.S. states requesting fewer numbers of triploid Grass Carp to stock than more humid and eastern U.S. states (MICRA 2015). Western U.S. states, such as New Mexico, Nevada, Utah, and California, received <1,000 triploid Grass Carp per year between 2002 and 2012 (MICRA 2015). An exception is in Arizona, which received 45,000 triploid Grass Carp per year between 2002 and 2012 (MICRA 2015). Fewer requests in more arid regions than humid regions are consistent with the original prediction in this study that arid regions have less water bodies and therefore less demand for vegetation control via triploid Grass Carp. Alternatively, fewer requests in more arid regions could be attributed to lack of access for triploid Grass Carp. Nationwide, 393 dealers or production facilities existed in 2012, with 95% of the dealers or facilities located in central and eastern U.S. states (MICRA 2015). In Texas, all dealers are located in central and eastern Texas. From 1992 to 2020, private landowners were required to purchase triploid Grass Carp from a Texas dealer that possesses a TPWD-issued Exotic

Species Permit to accept, hold, and distribute triploid Grass Carp from production facilities, thereby increasing costs to transport triploid Grass Carp to west Texas ecoregions. As of January 2021, permit holders can purchase USFWS-certified triploid Grass Carp from authorized dealers across state lines.

Submergent vegetation and emergent vegetation were the most cited vegetation type among permit applications. Grass Carp are most effective on submergent vegetation (Colle et al. 1978, Van Dyke et al. 1984, Leslie et al. 1987) but can consume emergent vegetation opportunistically (Cassani et al. 1995, Masser 2002). Permits were issued about equally for submergent and emergent vegetation, although identification of submergent and emergent vegetation can be problematic for landowners given that submergent vegetation can appear to be emergent at times and emergent vegetation can appear submergent at times, pending phenology and water levels (Egertson et al. 2004, Lembi 2009). Grass Carp are less effective on controlling filamentous algae and floating vegetation (Kay 1990, Masser 2002), which likely explains why 16% of the permit denials were attributed to "Grass Carp are not effective on the species of plant in the water body". However, 15% of permits listed filamentous algae and floating vegetation as the primary vegetation type.

Expenditures related to stocking of triploid Grass Carp varies nationwide. Application process fee ($16.00) and permit fee per fish ($2.00) required by TPWD is like other states. Per state agency websites, other U.S. states require application processing fees (e.g., $10.00 in Virginia, $50.00 in California, $94.00 in Washington), permit fee per fish (e.g., $1.00 in South Carolina, $15.00 in California), or both application process fees and permit fees per fish. Some states do not require permits (e.g.,

Oklahoma), or application processing fees or permit fee per fish (e.g., Florida), whereas Oregon requires a $5.00 fee per fish to cover costs associated with implanting Passive Integrated Transponders (PIT) tag in each fish to track escapement. Expenditures associated with triploid Grass Carp stocking, however, are considered more cost effective than alternative controls of nuisance vegetation (Shireman et al. 1985, Mitchell and Kelly 2006, MICRA 2015). Although cost estimates are dated, treatment of nuisance vegetation is 3 to 5 times greater with herbicide control (Shireman et al.1985, Cassani 1995) and 2 to 28 times greater with mechanical control (Cassani 1995, Cooke et al 2005) in comparisons to control with Grass Carp.

Characterization of triploid Grass Carp stocking in private waters of Texas provides insight into the practice and economics of using triploid Grass Carp as a control for nuisance vegetation, but several questions remain that, when answered, can benefit future private landowners as they decide to invest in biological control of nuisance vegetation and regulatory agencies in charge of stocking programs. Questions include: how many of the permitted triploid Grass Carp were purchased for stocking, were triploid Grass Carp effective in controlling nuisance vegetation per vegetation type, per water body size, and per ecoregion, were triploid Grass Carp used as sole or as part of a vegetation plan to control nuisance vegetation integrated with chemical treatments, what were the motivations for requesting supplemental stocking, and were stocking densities, set by TPWD, sufficient to control nuisance vegetation? Follow up surveys are used to assess management applications (Steinkoenig 1993, Bonar et al. 2002); therefore, these questions could be addressed in post-stocking surveys as part of the application process.

Another valuable question to be addressed is the escapement potential of triploid Grass Carp into public waters, which is a primary concern for the use of triploid Grass Carp and rationale for TPWD permitting process (Dibble and Kovalenko 2009, MICRA 2015, Chilton 2018, USFWS 2018). With about 800,000 triploid Grass Carp permitted to be stocked in private Texas waters between 1992 and 2020, has the number of Grass Carp taken from public waters increased during the same time period? Diploid and triploid Grass Carp populations exist in the lower Trinity River, San Jacinto River, and several drainages within the Galveston Bay drainage, attributed to escaped fish from Lake Conroe experimental stocking or from illegal introductions (Trimm et al. 1989, Bain et al 1990, Chilton and Poarch 1997, Elder and Murphy 1997, Webb et al. 2000). Since 1992, only 45 occurrences of Grass Carp were taken from water bodies in Texas (Hendrickson and Cohen 2015). Majority (60%) are reported from Harris County (i.e., Galveston Bay drainage). Remaining 40% were reported from 12 Texas counties, in lentic and lotic waters, between 2000 and 2015, and unknown if the water bodies were permitted for stocking. Therefore, escapement of triploid Grass Carp outside of site of initial introduction does not appear to be a major concern currently, but a subject to address, along with other questions, as private landowners and public entities continue to use triploid Grass Carp as control for nuisance aquatic vegetation.

Implications to sustainability, recommendations, and conclusion

Triploid Grass Carp are a useful and cost-effective example of species management use with sustainable implications as a biological control of aquatic vegetation. Overall track record shows that there are utilization benefits along with

environmental risks but understanding if the benefits outweigh the risk is still unknown. Largely, this case study focuses a sustainability approach to improve understanding of state regulation of triploid Grass Carp and provides a document of analysis to stand as a lasting history and record of the TPWD triploid Grass Carp permitting system with a call for more in-depth record keeping. Through improvements to the current permitting system and the incorporation of follow up with private landowners, clarification on effectiveness and satisfaction, particulars on individual practice of use, and determining the actual number of fish stocked can better assess the sustainability of triploid Grass Carp and of biological controls in general. This study should be an incentive for other states to follow similar approaches to their state regulatory practices of exotic species used as biological controls to not only meet the goals set by USFWS but to allow future research into the understanding of regional sustainable management and planning with support of managerial goals for ecological persistence.

Negative ecological impacts associated with triploid Grass Carp and if significant numbers escape from private to public waters in Texas is still unknown. Thus, recommendations also call for increased reporting of Grass Carp taken or sampled in Texas as past records are likely incomplete or give a limited outlook regarding documentation of triploid Grass Carp in public waters. Past studies have tracked escapements of triploid Grass Carp from public Texas waters via use of PIT tags to follow movements and behaviors (Bain et al. 1990, Chilton and Poarch 1997). Incorporating PIT tag requirements to the permitting system for fish stocked in areas of concern or conducting future studies as pertains to tracking movements of fish stocked in

private rather than public waters could further clarify escapement risks and help determine severity of ecological impacts associated with private water introductions.

This study provides a baseline for understanding triploid Grass Carp use in private Texas waters and describes an era of permitting (1992-2020) but many questions remain. With new rules set by TPWD as of 2021 including the ability to purchase triploid Grass Carp over state lines, an online permitting system that streamlines the permitting process, and the start of an 18-month expiration date on all permits, in which all fish must be stocked in this time period, some gaps in information might be filled and changes to distribution of use in Texas may occur. By determining the scope of change due these new regulations and by incorporating the recommendations herein, the viability of triploid Grass Carp as a safe, long term, and overall sustainable management practice as a biological control for aquatic vegetation can be better assessed.

Table 1. Column titles (variables) and descriptions of Texas Parks and Wildlife Department (TPWD) triploid Grass Carp permit application database.

Variable	Description
Permit ID number	A unique five-digit code assigned to all permit applications.
Applicant ID number	A two- to five-digit code generated to protect privacy of applicants' name; enabled the ability to track repeat stocking requests of applicants.
Water body ID number	A five-digit code generated to protect privacy of applicants' location.
TPWD-Inland Fisheries District	14 TPWD IF districts that permits are assigned for processing respective to location of the water body.
County	Texas county that the water body to be stocked is located; enabled grouping of permits into respective ecoregions of Texas for spatial comparisons.
Date application received	(y/m/d): date permit was received by the respective TPWD IF District; enabled grouping permits into years for temporal comparisons.
Date permit was issued/denied	(y/m/d); date permit was accepted or denied.
Number of triploid Grass Carp requested	N of Grass Carp requested; TPWD may adjust quantities upon review/inspection prior to issuing permits.
Water surface area	Acreage of the water body, converted to hectare; estimated by applicant.
Vegetation surface area	<50% coverage; >50% coverage, estimated by applicant; determines consideration of stocking rate.
Vegetation type	Characteristic of nuisance vegetation to be controlled, based on applicant response.
Water supply type	Nature of the water supply to the water body requested to be stocked, based on applicant response.
Discharge location	Basic description of where the water body to be stocked discharges, based on applicant response; lends information on escapement potential.
Presence of a barrier or spillway	Characteristic of the water body to be stocked, based on applicant response; lends information on escapement potential.
Accepted permit/reason for permit denial	If the permit was accepted or denied, lists reasons for denial; denied permits were not recorded in the database until 2005.

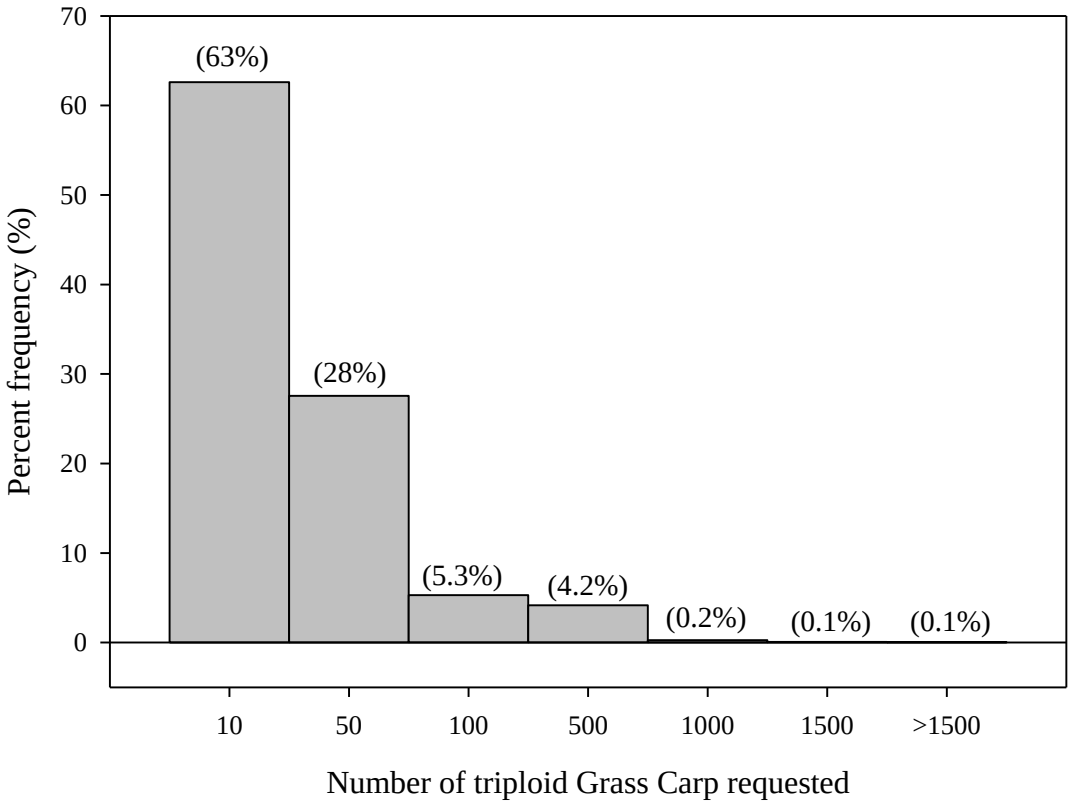

Figure 1. Percent frequency of the number of triploid Grass Carp requested among 30,387 permit applications submitted to Texas Parks and Wildlife Department between 1992 and 2020.

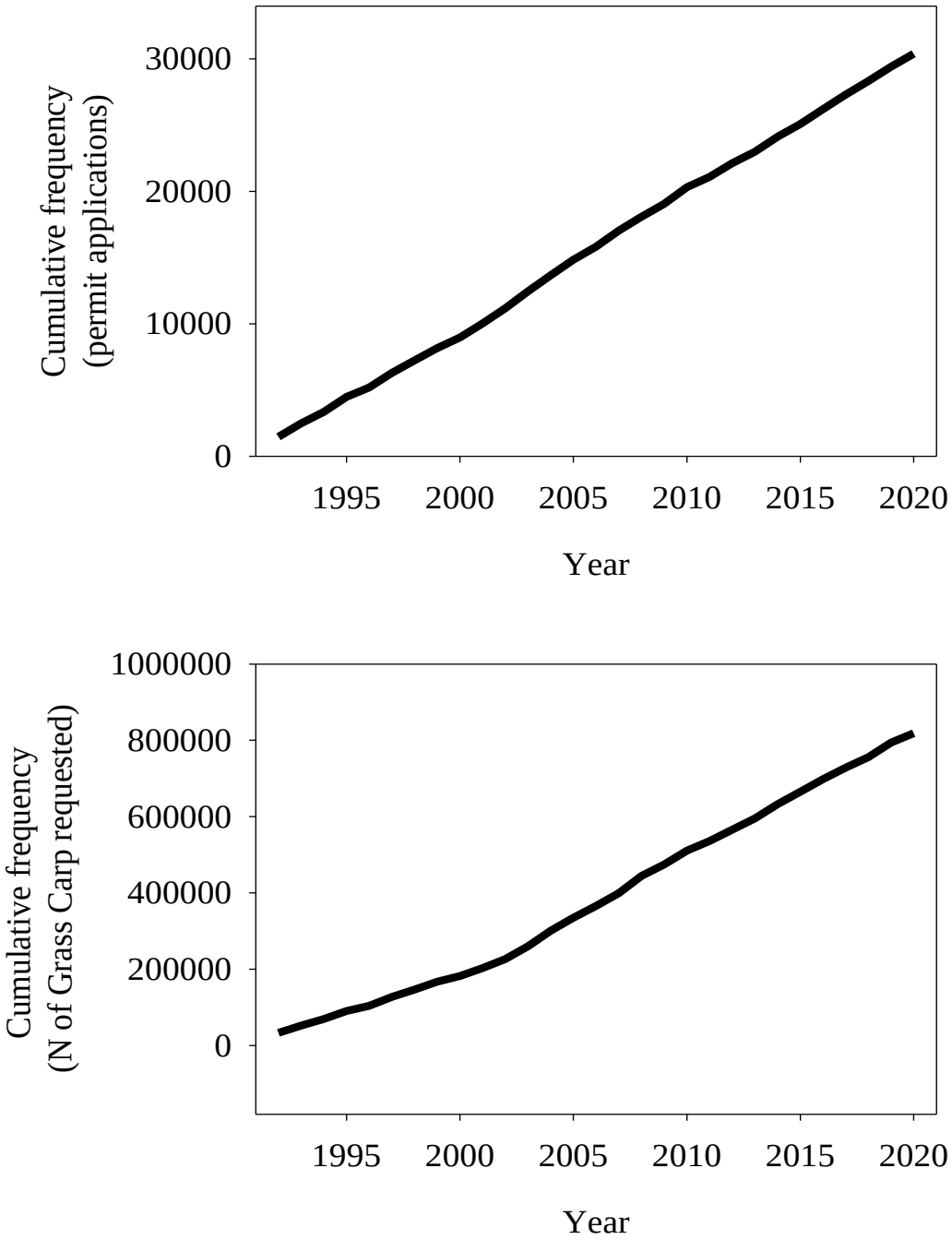

Figure 2. Cumulative frequency of number of permits applications (top panel) and number of triploid Grass Carp requested (bottom panel) among years for private water stocking permits submitted to Texas Parks and Wildlife Department between years 1992 and 2020.

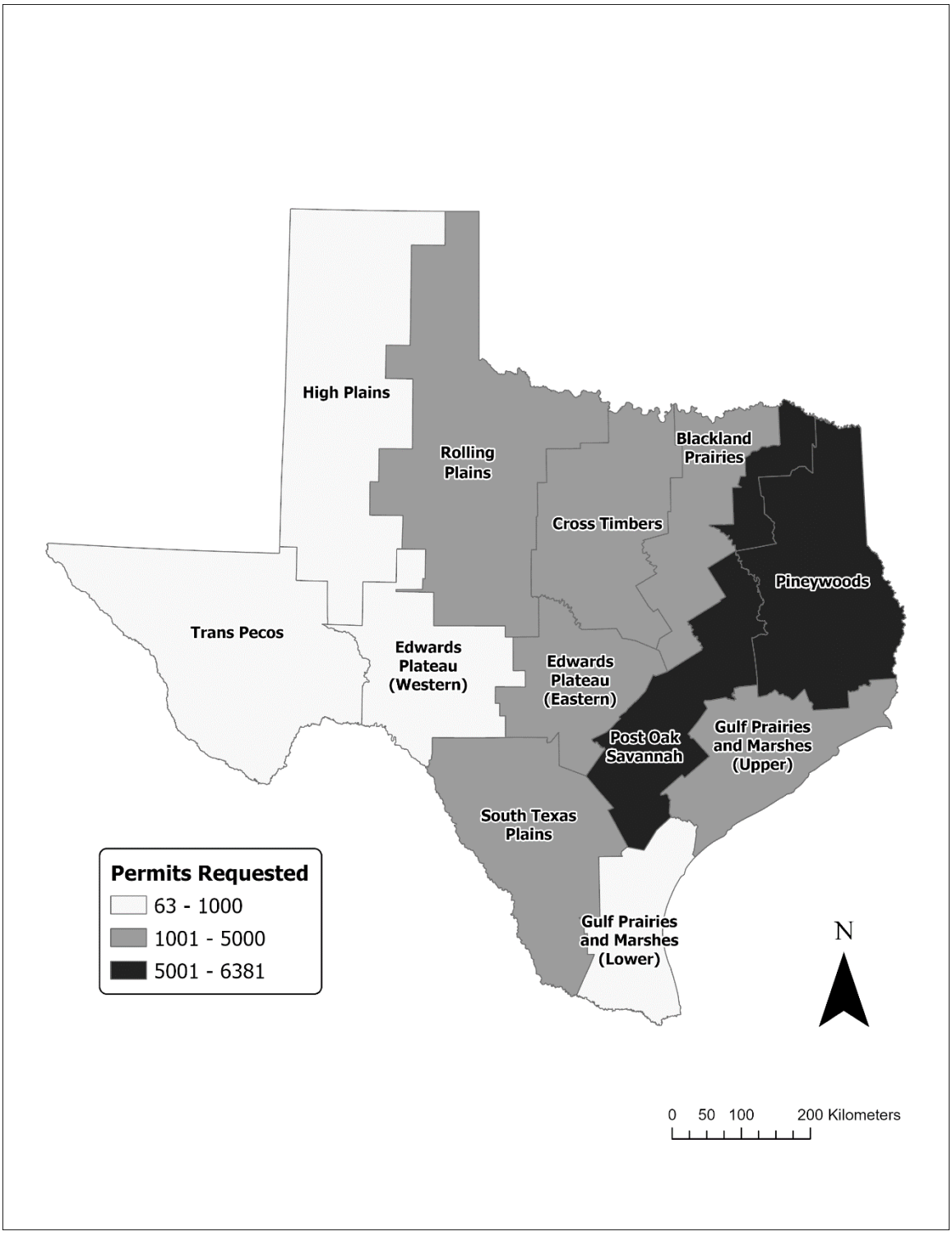

Figure 3. Number of triploid Grass Carp permit applications submitted by private landowners to Texas Parks and Wildlife Department between 1992 and 2020. Lighter colors represent fewer number of permits submitted, and darker colors represent greater numbers of permits submitted.

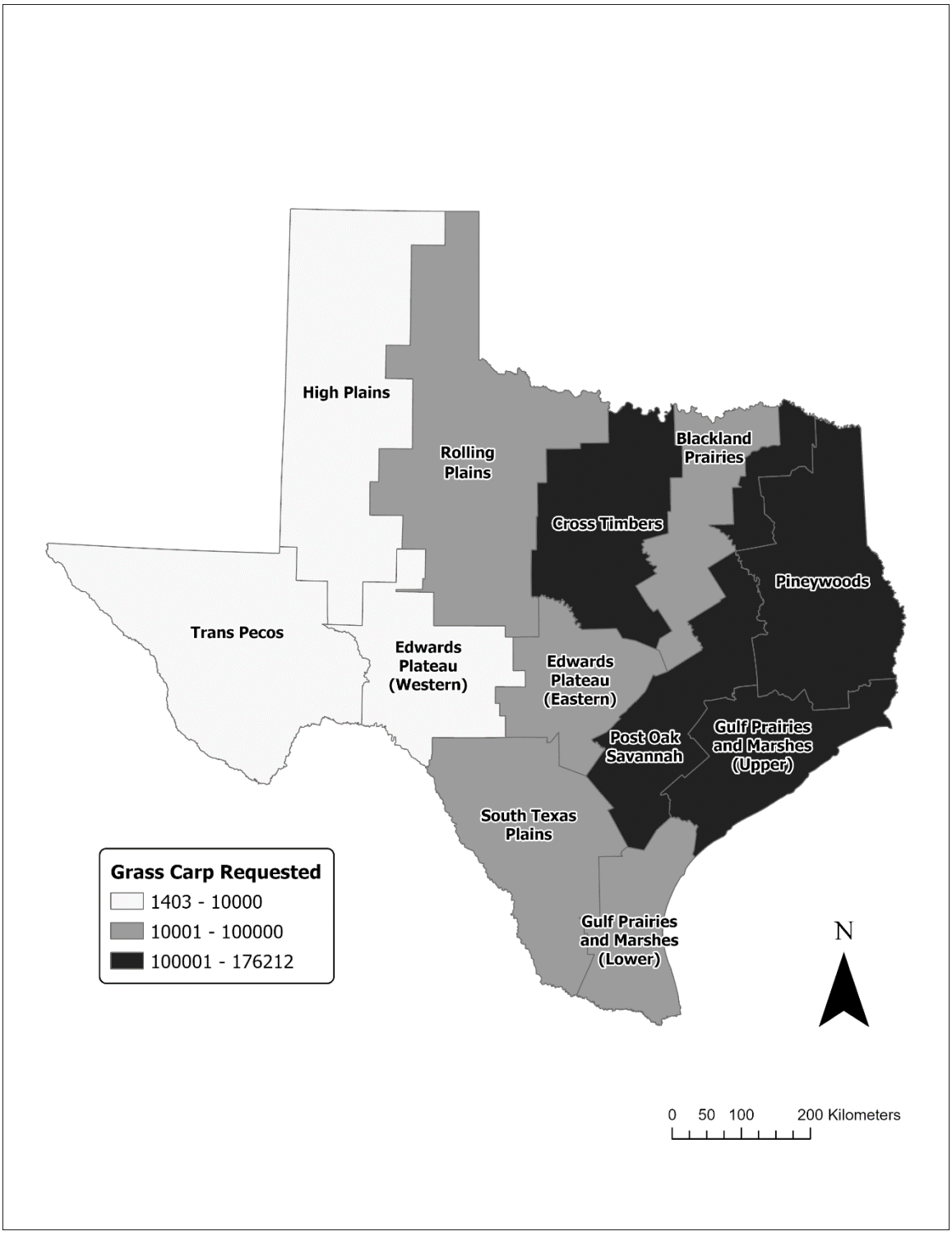

Figure 4. Number of triploid Grass Carp requested by private landowners to Texas Parks and Wildlife Department between 1992 and 2020. Lighter colors represent fewer number of triploid Grass Carp requested, and darker colors represent greater numbers of triploid Grass Carp requested.

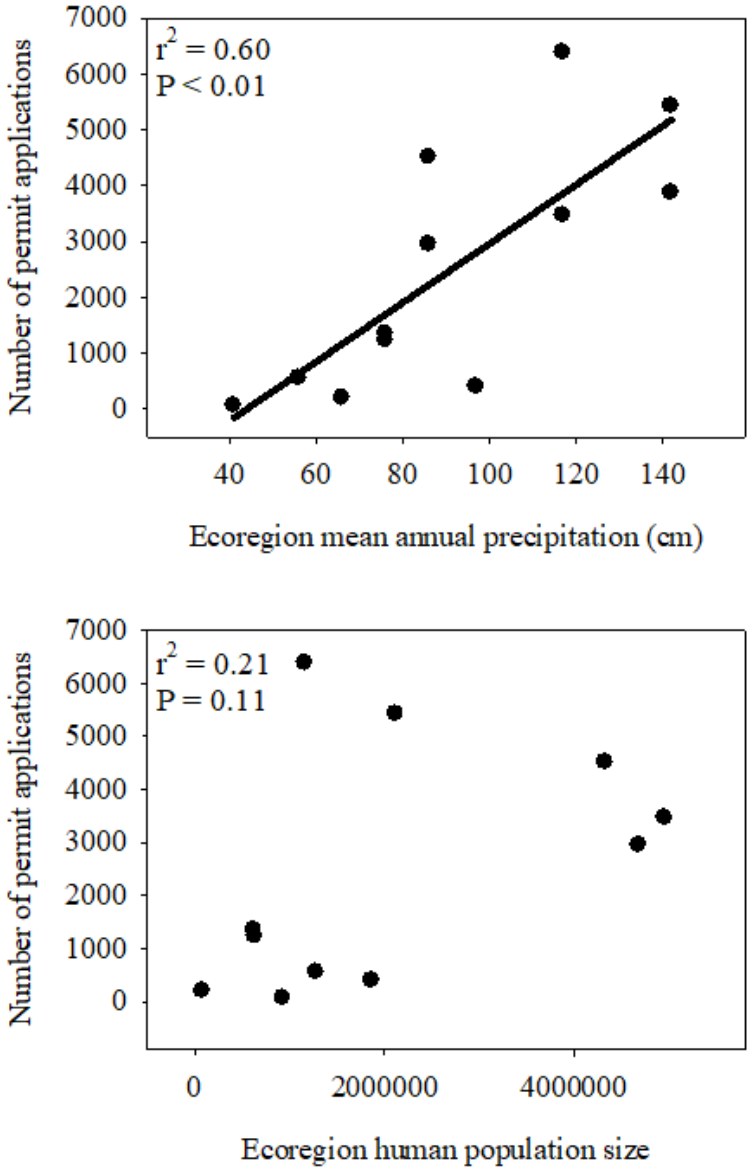

Figure 5. Correlationship between number of triploid Grass Carp permit applications and ecoregion mean annual precipitation (cm; top panel) and between number of triploid Grass Carp permit applications and ecoregion human population size (bottom panel) for permit applications submitted to Texas Parks and Wildlife Department between 1992 and 2020.

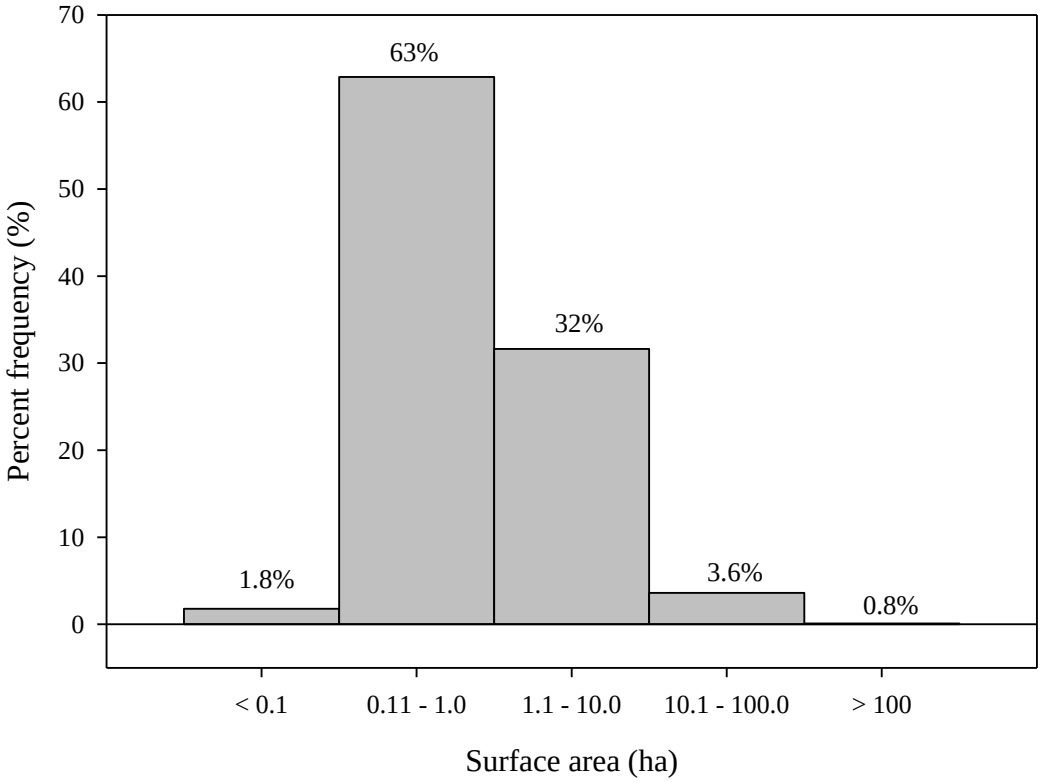

Figure 6. Percent frequency of water surface area (ha) among triploid Grass Carp permit applications submitted to Texas Parks and Wildlife Department between 1992 and 2020.

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