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A Triploid Grass Carp Risk Analysis Specific to Florida

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ABSTRACT

Three hydrilla (*Hydrilla verticillata*) biotypes are resistant to fluridone, the principal herbicide used in Florida. Because of an anticipated demand for triploid grass carp (*Ctenopharyngodon idella*), a risk analysis was conducted to examine the use of triploid grass carp to control hydrilla in large (>200 ha), open systems in Florida. An expert panel utilized the Generic Nonindigenous Aquatic Organisms Risk

Analysis Review Process developed by the Aquatic Nuisance Species Task Force to assess five hydrilla management options. Specifically, the panel assessed the risk of (1) eliminating all vegetation for three years or more; or (2) vegetation coverage exceeding 50% for five consecutive years. Herbicide application, followed by stocking low levels of triploid grass carp and subsequent herbicide treatment, was considered to be a lower risk option to achieve hydrilla management objectives. The expert panel emphasized the necessity of implementing well-supported system management and monitoring and determining stocking rates on a lake-by-lake basis.

Key words: aquatic macrophytes, biological control, *Ctenopharyngodon idella*, fluridone resistance, *Hydrilla verticillata*, risk analysis.

INTRODUCTION

Florida has an abundance of shallow (<5m) natural lakes with diverse emergent and submersed plant communities.

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Hydrilla (*Hydrilla verticillata*) has been a problematic non-native submersed aquatic plant in Florida for the past 40 years. This species has competitive advantages over native plants, and its prolific growth has reduced native macrophyte abundance and diversity. State agencies spent nearly \$69 million to control hydrilla from 2001-2006 (Florida Department of Environmental Protection archived reports), primarily chemical control using fluridone, which selectively targets hydrilla with appropriate application rates and timing. At least three biotypes of hydrilla have developed a resistance to fluridone (Michel et al. 2004). These biotypes are prevalent in 20 water bodies throughout central Florida ranging in size from 120 to 8500 ha, including the interconnected Kissimmee chain of lakes (Hoyer et al. 2005).

Triploid grass carp (*Ctenopharyngodon idella*) are an effective hydrilla bio-control agent. However, triploid grass carp (TGC) also consume desirable native plant species. Because of the difficulty in predicting TGC consumption rates and mortality, this species is not permitted by the Florida Fish and Wildlife Conservation Commission for release in large (>200 ha), interconnected systems.

The loss of fluridone as a cost-effective control of hydrilla has led to the investigation of other solutions, including development of replacement herbicides and bio-controls. A hydrilla management workshop conducted in 2005 examined control options (Hoyer et al. 2005), and use of TGC was a persistent workshop theme. In response to the potential call for wider use of TGC as a bio-control, risk analysis was employed to assess various risk management options for stocking this fish in large open-water systems.

METHODS

The Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process for estimating risk associated with the introduction of nonindigenous aquatic organisms and how to manage for that risk (hereafter referred to as "Generic Analysis"; ANSTF 1996) was utilized as a framework for structured discussion to achieve the project objectives. This methodology has been used primarily to address non-native fish species by federal and state agencies (Hill and Zajicek 2007) and as a means to assess non-native species ecological risks in Canada (Mandrak and Cudmore 2004).

The Generic Analysis consists of three steps: (1) Initiation, a request or need to evaluate an organism; (2) Risk Assessment, the qualitative assessment of the probability and consequences of establishment by an expert panel; and (3) Risk Management, the identification of policies, regulations, and operational measures to reduce unacceptable risks through adaptive management that includes a monitoring system to revise and update risk management activities over time (adaptive management).

In this case, risk analysis was initiated in anticipation of demands to stock TGC to control hydrilla in large or connected Florida lakes. An expert panel was assembled consisting of 13 experts in aquatic plants, grass carp, angling, waterfowl, freshwater ecology, freshwater fisheries, and water management (water supply, flood control), representing state and federal agencies, universities, and TGC producers. Experts were identified by a steering committee that explicitly sought

knowledgeable individuals that held professional positions of responsibility that would actively contribute to the analysis by synthesizing and expressing their experience, understanding and education relative to Florida's climate, hydrology, habitat alteration, flora, fauna, and biological and ecological processes.

The panel participated in two workshops. In the first, participants reviewed and edited a literature review of TGC management practices, biology, and ecological effects. The literature review provided a concise summary for the expert panel to build a synthesis of knowledge and experience to complete the risk analysis. In addition, the Generic Analysis was discussed to ensure that all panelists were familiar with the methodology, approach, and assumptions. The second workshop was primarily devoted to completing the risk analysis. The expert panel was directly involved throughout the process to achieve balanced perspectives of very complex social, biological, and ecological issues of assessing risk (an opportunity to be critical), identifying risk management options (an opportunity to be creative), and implementing an operational plan (an opportunity to recognize and compensate for logistical and financial limitations).

The Generic Analysis uses three qualitative categories to assess risk:

- Low: Acceptable risk; little concern; no mitigation required
- Medium: Unacceptable risk; moderate concern; mitigation required
- High: Unacceptable risk; major concern; mitigation required

The Generic Analysis accounts for uncertainty of the methodology, biotic and abiotic information, stochastic events, and expert panel member characteristics, by requiring the expert panel to identify a level of certainty for each risk estimate. The expert panel slightly revised the definition for each certainty code suggested in the Generic Analysis.

Very Certain (VC)	Sufficient data to support certainty
Reasonably Certain (RC)	Good but not extensive data or experience
Moderately Certain (MC)	Limited data or experience
Reasonably Uncertain (RU)	Very limited data
Very Uncertain (VU)	A guess

For the TGC risk analysis, experts used a modified framework, with risk estimates from 10 (high risk of occurrence) to 1 (low risk). Low risk (acceptable) ranges from 1-3, medium risk from 4-7 (moderate concern), and high risk (major concern) from 8-10. Certainty assessments followed the Generic Analysis.

The Generic Analysis endeavors to assess the Overall Risk Potential of an organism by combining estimates of the probability of establishment together with the consequences of es-

tablishment. Because this project involves intentional TGC stocking, the probability of establishment was not considered.

An important aspect of this project was assessing the risk of a limited number of specific outcomes of TGC stocking. Rather than consider an overwhelming suite of possible secondary consequences of TGC stocking (e.g., fish community structure, phytoplankton, water quality, waterfowl), experts determined two unacceptable outcomes with respect to aquatic plant abundance. Not all participants in this risk analysis objected to short term elimination of all plants, but complete vegetation removal with no re-growth for three or more years was considered unacceptable. Fish populations can sustain a few missing cohorts, and waterfowl can move to other water bodies, although extended vegetation-free periods increase the risk of birds not returning. Conversely, hydrilla coverage exceeding 50% of the water body for a five-year period was unacceptable to most experts, particularly surface water managers concerned with potential flooding from obstruction of water conveyance and control structures.

In light of these unacceptable outcomes, four hydrilla management options, discussed by Hoyer et al. (2005), were considered along with a fifth option, ultra-low stocking, added by the expert panel during the second workshop. Based on previous research in the published literature, the expert panel refined the management options by identifying stocking rates, time periods to achieve vegetation control, and desired vegetation coverage. Management actions are triggered by > 50% total vegetation coverage.

Options:

1. High TGC stocking rate followed by TGC removal: Implement high stocking rates to eliminate hydrilla rapidly. Follow this by efforts to reduce and manage triploid grass carp populations (i.e., removal techniques, barriers, and controlled mortality) to achieve hydrilla control, while allowing re-vegetation by native species. Option 1 stocking rate ranges from 25 to 50 fish per hectare (10 to 20 fish per acre) within a time frame of 18 months to achieve vegetation coverage of 25% to 50% (all species).
2. Low TGC stocking rate: Implement stocking rates at low levels, with subsequent assessment and adjustment of stocking to maintain lower levels of aquatic plant coverage than the initial problematic abundances. Option 2 stocking rate ranges from 1 to 12 fish per hectare (0.5 to 5 fish per acre) within a time frame of five years to achieve vegetation coverage of 25% to 50% (all species). Supplemental stocking should occur no sooner than three years after the initial stocking.
3. Herbicide treatment with low TGC stocking rate: Initial herbicide treatment to achieve 20% vegetation coverage followed by stocking low levels of triploid grass carp to maintain hydrilla management objectives. Option 3 stocking rates range from 1 to 7 fish per hectare (0.5 to 3 fish per acre) within a time frame of five years to achieve vegetation coverage of 25% to 50% (all species). No supplemental stocking.
4. Integrated hydrilla management: Utilize all available plant control methods including triploid grass carp, herbi-

cide, water level manipulation, mechanical, and other biological control (i.e., insects). Option 4 stocking rates of 1 to 12 fish per hectare (0.5 to 5 fish per acre) within a time frame of five years to achieve vegetation coverage of <5% hydrilla and 25% to 50% (all species). Supplemental stocking may be required on an as-needed basis (adaptive management).

5. Ultra-low TGC stocking rate: Triploid grass carp stocking to control an incipient hydrilla population. Option 5 stocking rate of <1 fish per hectare (0.5 fish per acre) within a time frame of five years to achieve vegetation coverage of <5% hydrilla and 25% to 50% vegetation coverage (all species). Supplementally stock TGC as needed.

Consensus risk estimates for five management options assume resources are available (manpower, equipment, and funding) to conduct appropriate lake management (flora, fauna, and water quality monitoring) and current technology is employed.

RESULTS

Unacceptable Risk Scenario I: Complete vegetation removal for three or more years

Management Option 1 - High TGC stocking rate followed by TGC removal

Members were reasonably certain that there was a high risk that vegetation would be completely eliminated for three years or longer with option 1 (Table 1). Removal of TGC from large systems is logistically impractical, and it is not feasible to monitor TGC abundance (Colle et al. 1978, Schramm and Jirka 1986, Santha et al. 1991, Bonar et al. 1993, Duncan 2002, Willis et al. 2002, Thomas 2004). However, TGC mobility creates concern that large numbers of fish may result in vegetation removal in connected non-target lakes, as well as uncertainty about the duration of hydrilla control if TGC emigrate from the target water body.

TABLE 1. RISK ANALYSIS PARTICIPANTS' CONSENSUS NUMERICAL RISK RATINGS, OR RANGE OF RISK RATINGS, WITH UNCERTAINTY CODES FOR THE UNACCEPTABLE RISK SCENARIO OF COMPLETE VEGETATION REMOVAL FOR THREE OR MORE YEARS.

Management Options	Risk Rating									
	High			Medium				Low		
	10	9	8	7	6	5	4	3	2	1
1) High TGC stocking rate	RC	-	10							
2) Low TGC stocking rate										RU
3) Herbicide treatment with low TGC stocking rate										RC
4) Integrated hydrilla management										RC
5) Ultra-low stocking										VC

Uncertainty Codes: VC - Very certain RC - Reasonably certain RU - Reasonably uncertain

Management Option 2 - Low TGC stocking rate

This management option was estimated to present a medium-high risk (5-8) of extended vegetation removal. Although the expert panel commented that: (1) low stocking rates have been successful in small, closed systems or very specific waterbody configurations (e.g., Lake Miccosukee, Jefferson/Leon counties, Florida), and (2) monitoring TGC abundance as a basis for supplemental stocking is far more difficult in larger water bodies. Furthermore, public impatience with the low rate of plant removal may result in incremental stockings that could result in vegetation eradication. The experts' wide risk range and lack of certainty (reasonably uncertain) reflect varying lake conditions (e.g., hydrilla tubers density in the sediments, initial hydrilla abundance) that might substantially alter the outcome. The longer term, five-year time period also increases the potential for stochastic events (e.g., extreme rainfall or temperature) to play a larger role in influencing vegetation coverage, but risk would be reduced with periodic vegetation assessment.

Management Option 3 - Herbicide treatment with low TGC stocking rate

Participants were reasonably certain this management option yielded a lower risk (2-3) of producing no vegetation for three or more years. After herbicide application reduces coverage to 20%, a low level TGC stocking can be based on lake physical, chemical, and biological characteristics, and vegetation management objectives could be maintained with periodic herbicide applications.

Management Option 4 - Integrated hydrilla management

Integrating a variety of hydrilla management practices was considered a desirable low-risk (2-3) option. However, most of the potential techniques have very limited application for many large Florida water bodies. The expert panel commented that the required timing and magnitude of lowering water levels is difficult due to Florida's rainy seasons and access issues; however, successful water level manipulations in Florida for weed control in large lakes (e.g., Lake Istokpoga) have been accomplished. Mechanical removal is expensive for large areas and generally used only to create boat trails. To date, no insects have been found that effectively control hydrilla. In essence, the low risk indicates the realization that the effective components of an integrated approach are limited to herbicide applications and TGC, which is identical to Option 3.

Management Option 5 - Ultra-low TGC stocking rate

Participants rated this option as the lowest risk (1) of eliminating vegetation. However, the opportunities to employ this approach are very limited. Although this technique has been successful in several smaller Florida water bodies (<200 ha surface area), Lake Miccosukee (2500 ha, Jefferson/Leon counties) is the only instance where an ultra-low level stocking has been practiced to control hydrilla in a large water body. This lake has continuous extensive coverage of emergent plants (>90%), is shallow, and TGC were stocked to control an incipient hydrilla population.

Unacceptable Risk Scenario II: No/limited vegetation control (>50% of the water body for a five-year period)

Management Option 1 - High TGC stocking rate followed by TGC removal

The experts were reasonably certain that high stocking rates present a low risk (1-3) that no or limited vegetation control would occur (Table 2). Extensive literature confirms the likelihood of substantial plant removal at the stocking rates prescribed in this option.

Management Option 2 - Low TGC stocking rate

The members identified a low-medium risk (3-5) that a low stocking rate would lead to unacceptably high vegetation abundance. However, they were reasonably uncertain in their assessment of this risk because the impact of TGC mortality is more pronounced at low stocking rates. The possibility of public clamor for additional stockings would reduce the risk of no vegetation control, but increase the likelihood of eliminating all submersed vegetation (Risk Scenario I).

Management Option 3 - Herbicide treatment with low TGC stocking rate

This option was rated at low risk (1-3) of failing to control vegetation because of the effectiveness of initial and subsequent herbicide applications. This risk does not consider the high cost of the current effective herbicides, which might curtail the area treated or the frequency of follow-up treatments.

Management Option 4 - Integrated hydrilla management

Similar to Risk Scenario I, integrating a variety of hydrilla management practices yielded a desirable low risk (1-3) yet impractical option. As a result, the risk profile is identical to that for option 3.

Management Option 5 - Ultra-low TGC stocking

This management option is not applicable because the initial very low levels of hydrilla are below the 50% vegetation coverage action threshold.

TABLE 2. RISK ANALYSIS PARTICIPANTS' CONSENSUS NUMERICAL RISK RATINGS, OR RANGE OF RISK RATINGS, WITH UNCERTAINTY CODES FOR THE UNACCEPTABLE RISK SCENARIO OF NO OR LIMITED VEGETATION REMOVAL (>50% OF THE WATER BODY FOR A FIVE-YEAR PERIOD).

Management Options	Risk Rating									
	High		Medium				Low			
	10	9	8	7	6	5	4	3	2	1
1) High TGC stocking										RC - {3 to 1}
2) Low TGC stocking										RU - {5 to 3}
3) Herbicide with low TGC stocking										RC - {3 to 1}
4) Integrated hydrilla management										RC - {3 to 1}
5) Ultra-low stocking										Not applicable

Uncertainty Codes: RC - Reasonably certain RU - Reasonably uncertain.

DISCUSSION

An unusual aspect of this risk analysis is the opposing nature of the unacceptable outcomes (i.e., too much or too little control). Minimizing risk for one outcome increases the likelihood of the opposite outcome. The third option, an initial herbicide application to achieve minimal hydrilla coverage followed by stocking low levels of triploid grass carp, offered lower (acceptable) risks for either scenario. However, the panel noted many caveats in the implementation of this approach in large, open Florida waters, and a "cook-book" formula for stocking TGC was not recommended. Many factors must be considered prior to stocking, and ongoing management is essential post-introduction activity. A pre-stocking management plan must be developed on an individual lake basis to adequately consider limnological and morphometric conditions, as well as surrounding land use. Shallow lakes with relatively firm substrates and good light penetration are favorable for re-establishment of native vegetation and may buffer the risk of plant elimination for three years or longer. By contrast, flocculent sediments, in lakes with enough fetch, will result in wind-mixed turbidity that decreases water clarity and retards submersed plant growth. In these instances, low TGC stocking rates may prevent re-establishment of native plants for years. Shallow lakes may experience extreme low water levels, which elevates carp density and leads to over-grazing. Lakes with periodic high flow may trigger fish to leave the water body, increasing the risk of under-control.

Additional challenges to utilizing herbicides for Option 3 in large, open systems are: (1) high costs of available herbicides that may not specifically target hydrilla; (2) water outflow that may nullify or mitigate herbicide effectiveness; (3) downstream herbicide effects on non-target vegetation; and (4) herbicide effects associated with water withdrawn for irrigation or human consumption. TGC-associated concerns include: (1) maintaining adequate carp densities without barriers to emigration; and (2) determining appropriate stocking rates based on vegetation biomass and plant species composition.

Mixed species macrophyte communities are at lower risk for either unacceptable outcome. Most hydrilla populations can be controlled by herbicide with minimal non-target damage. The presence of unpalatable native plants will provide structure to support fisheries and aquatic communities (note: hydrilla resistance to fluridone herbicides upsets this strategy). However, colonization by unpalatable exotic plants may result in the replacement of hydrilla with a species more difficult or costly to manage (e.g., *Hygrophila polysperma* in south Florida).

Strong reservations were expressed by the expert panel concerning TGC stocking and management in large, unconfined water bodies (>200 ha), in part due to the movement patterns of triploid grass carp. Several studies have observed that mature grass carp move extensively (Bain et al. 1990, Cassani and Maloney 1991, Chilton and Poarch 1997, Maceina et al. 1999, Kirk et al. 2001) and may move to non-target areas (Bain et al. 1990, Cassani and Maloney 1991, Clapp et al. 1993, Chilton and Poarch 1997). Many types of barriers have been tested with regard to grass carp containment, both behavioral and physical, with none achieving greater than

80% deterrence and most significantly less (Maceina et al. 1999, FishPro 2004). Removal techniques have been similarly unsuccessful, and logistical constraints (cost and manpower) prevent the effective removal of triploid grass carp in large water bodies (Colle et al. 1978, Schramm and Jirka 1986, Bonar et al. 1993, Duncan 2002, Willis et al. 2002, Thomas 2004).

Managers choosing Option 3 must be aware that chemical application may decrease palatability and reduce feeding rates, which under this scenario would trigger additional herbicide use. Tooby et al. (1980) found that grass carp stopped feeding after exposure to herbicides (diquat and fluridone) at the recommended levels for plant control. Kracko and Nobel (1993) observed that plants treated with fluridone displayed 20% lower levels of nonstructural carbohydrates than those in untreated plants and that there was significantly less feeding on hydrilla exposed to the treatment. However, Florida field studies that combined use of fluridone and low-density stocking of grass carp for integrated control have been successful (Cassani 1996, Leslie et al. 1996). The TGC consumption trials of treated hydrilla may be important prior to implementation of integrated treatment.

A critical factor which weighed heavily in the risk analysis is determination of the correct stocking rate. Stocking rates of diploid and triploid grass carp based on vegetation biomass have been highly variable (Osborne and Sassic 1979, Shireman and Hoyer 1986, Leslie et al. 1994, Cassani et al. 1995, Hanlon et al. 2000, Bonar et al. 2002, Kirk and Henderson 2006). The stocking rate of Option 3 could range from 1 to 7 TGC/ha. The difference in these rates can be substantial, depending on plant biomass and species composition, and, under certain conditions, 1 TGC/ha can lead to over-control and 7 TGC/ha might produce no noticeable reduction. Leslie et al. (1993) noted that plant removal is slow when using grass carp, and patience or supplemental management methods are required. They also suggested that managers should underestimate the stocking rate, provide supplemental plant control, and/or slowly increase the stocking rate until plant management objectives are met.

Many factors affect the mortality of grass carp including stocking size, water temperature at stocking, hauling distance, and density (Carmichael et al. 1984). In general, the expert panel agreed that mortality rate of about 20% annually over the long-term (>10 years) and 5% annually over the short-term (<5 years) were reasonable estimates, but individual water bodies and stockings may vary (B. Jagers FL FWCC, pers. comm). This uncertainty presents a problem in avoiding the unacceptable outcomes. Increasing the stocking rate to account for higher mortality will increase the risk of vegetation elimination. Because of the difficulty of removing TGC, a conservative approach that assumes lower mortality offers the more practical alternative of additional herbicide treatments. The trade-off is a more costly, but less risky management approach.

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A final project report that includes the complete literature review can be viewed or downloaded from the Internet at: <http://www.FloridaAquaculture.com/pub.htm>. Scroll down to General Publications and click on "A Risk Analysis Pertaining to Triploid Grass Carp."

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