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Narrowing the Horizon: Using Known Invasives and Propagule Pressure to Focus Risk Screening Efforts on Potential Invasives

Jeffrey E. Hill [1,*], Allison Durland Donahou [1,2], Emily S. Wooley [1,3], Lauren N. Lapham [1,4] and Quenton M. Tuckett [1]

[1] Program in Fisheries and Aquatic Sciences, Tropical Aquaculture Laboratory, Institute of Food and Agricultural Sciences, School of Forest, Fisheries, and Geomatics Sciences, University of Florida, Ruskin, FL 33570, USA; adurland@flsouthern.edu (A.D.D.); emily@conserveturtles.org (E.S.W.); l.lapham@ufl.edu (L.N.L.); qtuckett@ufl.edu (Q.M.T.)
[2] Department of Biology, Florida Southern College, Lakeland, FL 33801, USA
[3] Sea Turtle Conservancy, Gainesville, FL 32609, USA
[4] Florida Fish and Wildlife Conservation Commission, Marathon, FL 33050, USA
* Correspondence: jeffhill@ufl.edu; Tel.: +1-813-671-5230

Abstract: About 11 million marine ornamental fish of ca 1800 non-native species are imported into the USA each year. Selecting species for risk assessment is daunting for such a diverse pathway. Herein, we discuss a focused method for species selection: choosing important taxa related to known invaders in high-volume pathways and narrowing prospective species lists to manageable groups of potential hazards. We provide an example using 11 damselfishes, a family with high volume in trade and one of the species established in USA waters. We used a specialized literature review and a risk screening tool (Aquatic Species Invasiveness Screening Kit) to provide an estimate of risk of invasiveness of marine waters of Florida. The established species was identified as a hazard and potential invasive. All other species scored well below the threshold for invasiveness and future climate had little effect on estimates of invasiveness. The analysis revealed little need for additional risk assessment or prohibitions on damselfishes in trade. Education, monitoring, and early detection and rapid response were the main risk management recommendations. The focused species selection process employed herein provided hazard identification and preliminary risk estimates for just 11 species, but collectively, they represent 40% by volume of fishes imported in the marine ornamental trade.

Keywords: Aquatic Species Invasiveness Screening Kit; damselfish; marine ornamental fish; *Neopomacentrus cyanomos*; Pomacentridae; risk assessment; risk screening

Key Contribution: We recommend focusing on non-native species in priority pathways (e.g., high volume and known invasive species) as a method of choosing species for risk assessment. We focused on prominent species of damselfishes in the marine ornamental trade, a group with a current established species in USA waters. All assessed species besides the established damselfish were scored as non-invasive. Focused species selection provides key information on risk of species in prominent pathways as an alternative to ad hoc selection or broad horizon scanning.

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1. Introduction

The worldwide trade in marine ornamental organisms is an important segment of the ornamental industry [1,2]. Though substantial numbers are imported into Europe, Japan, and other locations, the USA is the largest consumer of marine ornamental species [3]. The list of domestically cultured species is growing [4]; however, most marine ornamentals are wild-caught from reefs and other marine habitats of the Indo-Pacific [3,5]. Most imported marine ornamentals are landed at Los Angeles, California, though collectively considerable numbers are landed at other ports of entry such as New York, Chicago, San Francisco, and Miami (e.g., [6]). Marine ornamentals are then shipped around the USA and into Canada to wholesalers and distributed to aquarium stores [7]. Of the marine ornamental market, marine fishes are the dominant group imported into the USA [8]. Between May 2004 to May 2005, the import volume of marine fishes into the USA was about 11 million individuals of 1800 species from 125 families [3]. This figure does not include invertebrates (e.g., corals, crustaceans, and mollusks), domestically produced fishes, or domestically captured fishes (Florida and Hawaii).

Growth in trade may increase propagule pressure through the deliberate or accidental release of organisms [9]. The vulnerability of U.S. coastal waters to invasion by ornamental fishes is highlighted by two well-known invaders, Devil Firefish *Pterois miles* (Bennett, 1828) and Red Lionfish *P. volitans* (Linnaeus, 1758) [10,11]. Unfortunately, the only available management to this invasion was reactive. Little was known about lionfish until after establishment occurred, eradication was unlikely, and ecological impacts were documented [12,13]. One solution to this problem is pro-active application and implementation of risk screening tools which can be applied to a pool of potential invasive species before they become a problem. Literature review and risk screening can identify data gaps and inform additional risk assessment from which appropriate management actions can then be taken prior to species release and establishment [14,15].

Horizon scanning is increasingly used to prioritize species for risk assessment [16]. This process is used to evaluate potentially hundreds of species using a simple, uncalibrated scoring system and expert opinion to produce a list of priority species [17,18]. Methods for choosing the species that will be evaluated differ among horizon-scanning efforts, though most incorporate expert opinion of what is thought likely to invade within some future time frame along with geographic, climate, and pathway data (e.g., [17,19]). Online tools are available for producing preliminary species lists (e.g., CABI Horizon Scanning Tool [20]). The species on the post-evaluation list are properly classified as potential hazards and cannot, without further assessment, be accurately classified as actual hazards or risks (Box A1. Hazard vs. Risk). For example, due to the simplicity and uncertainty associated with the process, all species on a priority list from a horizon scan would require additional hazard identification as well as risk assessment to inform management. Although horizon scanning is useful if funding, time, and personnel are available, resources are somewhat evenly spread over numerous species, many of which will not be classified as hazards.

As an alternative or a supplement to horizon scanning, we propose narrowing the focus to taxonomic groups that contain known invaders within priority pathways. We expect that management agencies will prioritize pathways to include those delivering higher numbers and more impactful invasives. This procedure could be expanded to functionally similar groups if resources allowed [21]. Phylogenetic relatedness and functional similarity are thought to influence establishment success [22,23]. In addition, pathway volume is frequently considered a proxy for propagule pressure [24,25], which has a dominant influence on establishment success. Such an approach, one that is taxonomically restricted and pathway-based, provides a focused evaluation of greater depth and detail than a horizon scan but for specific taxonomic or functional groups. This method was used recently to identify lionfishes, subfamily Pteroinae, as a priority target group for risk screening in Florida, USA [13]. The group contains two invasive species in the region and additional species in the marine aquarium trade ranging from those nearly identical to the invaders to smaller, more specialized species [6,13]. Using this approach, we identified the family Pomacentridae (damselfishes) as a priority group for risk screening in Florida due to its high volume in trade and the establishment of one member of the family in the Gulf of Mexico (GOM). If this process is repeated for other important groups in trade, it could provide more detailed predictions of hazard status and risk and focus resources and management on some of the most likely future invaders.

Pomacentridae is one of the most important marine ornamental fish groups, including the top eight fish groups (two species entries include more than one species, Green Chromis *Chromis viridis* (Cuvier, 1830), a potential species complex [3], Clown Anemonefish

Amphiprion ocellaris (Cuvier, 1830), and Orange Clownfish *Amphiprion percula* Lacepède, (Cuvier, 1802)) imported into the United States in the marine ornamental trade [3] (see also [8]). Each pomacentrid group in the top eight has import volumes of 200,000 individuals or more annually. Collectively, over 4 million individuals of these species are imported annually, representing about 40% of all marine ornamental fish imports [3]. Evaluating high volume fish in trade is important because trade volume in aquarium species is thought to correspond to relative propagule pressure in the environment [24]. Moreover, many pomacentrids are inexpensive and frequently used to cycle bacteria in marine aquariums (a practice used to accelerate the ability of filters to process nitrogenous wastes); afterwards, these fish are removed and must be relocated to another aquarium or returned to a pet store. Some damselfish are released [26], increasing propagule pressure and the probability of establishment. The Regal Demoiselle *Neopomacentrus cyanomos* (Bleeker, 1856), was established first in the western GOM and spread east into Florida waters [27,28]. Recent records include the Florida Keys and waters off of Palm Beach County [26]. This species can provide a relative measure of invasiveness by comparison with scores of other pomacentrids. Another pomacentrid of concern, though not included in the top imported marine ornamentals, is the Spiny Chromis Damselfish *Acanthochromis polyacanthus* (Bleeker, 1856) due to sightings and collections in a marina within Miami Beach, although the status of this introduction is unknown [26]. The Regal Demoiselle and Tessellated Blenny *Hypsoblennius invemar* (Smith-Vaniz and Acero P., 1980) are the only two documented marine fish invaders established in the tropical western Atlantic besides lionfish, though several collections and sightings of the Warthead Blenny *Protemblemaria punctata* (Cervigón, 1966) in and near Tampa Bay suggest potential establishment [26].

Risk screening, assessment, and management frameworks have been used to identify and manage problem invaders but remain under-implemented for marine ornamental fishes in the USA trade (but see Lyons et al., 2020 [13] for lionfishes; Zajicek et al., 2009 [7] for a pathway analysis). By using appropriate methods such as species bioprofiles (e.g., [14,15]) and risk screens (e.g., Aquatic Species Invasiveness Screening Kit, AS-ISK; [29,30]), agencies and industry can more effectively manage non-native species by proactively identifying potentially invasive species and distinguishing them from those species that pose little risk. Our goal was to focus on a non-native species group with known invaders in a priority pathway (i.e., imported damselfishes in the marine aquarium trade). Specific objectives were (1) to assess the highest-volume damselfishes in trade, a known damselfish invader in the GOM, and a damselfish of concern collected in South Florida; and (2) to provide management recommendations based on the methodology and findings. Risk screening can improve the sustainability of the marine ornamental trade by informing decisions regarding priority species for further assessment or early detection and rapid response (EDRR).

2. Materials and Methods

Pomacentridae contains about 424 species [31], i.e., too many species to evaluate given the scarce resources allocated to risk assessment. We used Rhyne et al. (2012) [3] to identify the species with the highest trade volumes and added the Regal Demoiselle (established in the risk assessment area) and the Spiny Chromis Damselfish (a species collected in Miami Beach, Florida [26]). The final list included 11 total species that were evaluated for Florida, USA (the risk assessment area: Table 1). The assessments also have relevance for nearby waters of the GOM and southeast USA coast (e.g., [13]).

A bioprofile was prepared for each species using an established format created by the Florida Fish and Wildlife Conservation Commission (e.g., [14,15]). This format includes information on the biology, ecology, geography, invasion history, and human use of the species as well as sections including expert opinion on potential risks [32]. The bioprofiles are not necessary to complete AS-ISK assessments but facilitate their completion and further provide considerable information on risk to assist managers in decision making [15].

Table 1. Common and scientific names and trade status of 11 pomacentrids evaluated for invasiveness in marine waters of Florida. High trade volume imported into the U.S. as indicated in Rhyne et al. (2012) [3]. Green Chromis is a potential species complex and Clown Anemonefish and Orange Clownfish are combined in the dataset from Rhyne et al. (2012) [3].

Common Name	Scientific Name	High Trade Volume
Spiny Chromis Damselfish	*Acanthochromis polyacanthus*	No (collected in Miami Beach)
Clown Anemonefish	*Amphiprion ocellaris*	Yes
Orange Clownfish	*Amphiprion percula*	Yes
Green Chromis	*Chromis viridis*	Yes
Sapphire Devil	*Chrysiptera cyanea*	Yes
Azure Demoiselle	*Chrysiptera hemicyanea*	Yes
Goldtail Demoiselle	*Chrysiptera parasema*	Yes
Whitetail Humbug	*Dascyllus aruanus*	Yes
Blacktail Dascyllus	*Dascyllus melanurus*	Yes
Threespot Dascyllus	*Dascyllus trimaculatus*	Yes
Regal Demoiselle	*Neopomacentrus cyanomos*	No (established in Gulf of Mexico)

The AS-ISK is a generic risk screening tool developed to accommodate a wide range of aquatic taxa and environments [29]. It is based on the Fish Invasiveness Screening Kit (FISK), a tool with an extensive history of application internationally and in the United States, including Florida, for the assessment of potentially invasive freshwater fish (e.g., [33–35]). The AS-ISK meets all standards for risk assessment contained in Roy et al. (2018) [36]. It is a useful method for assessing the risks of non-native marine fishes as indicated in the recent lionfish risk assessment for Florida (see [11]) and in international applications (see [30]). The AS-ISK is freely available online from the Centre for Environment, Fisheries and Aquaculture Science (https://www.cefas.co.uk/services/research-advice-and-consultancy/non-\protect\unhbox\voidb@x\hbox{n}ative-species/decision-support-tools-for-the-identification-and-management-of-invasive-non-native-aquatic-species/, accessed on 29 March 2023).

Screens were completed for each species by two independent assessors. The assessments provided mean scores for the Basic Risk Assessment (BRA, consisting of 49 questions related to invasiveness under current conditions), mean scores for the complete assessment, which includes the BRA plus the Climate Change Assessment (CCA, 5 questions related to the effect of future climate change on risk of establishment and impact), a range of scores (maximum, minimum, and delta), index of certainty (CF, certainty factor) of the assessments (BRA, CCA, and BRA+CCA), and specific justifications for each answer to risk screen questions. Mean scores were evaluated for risk level using an analysis of AS-ISK assessments of global marine fish invaders, which provided a medium- versus high-risk threshold value of 12.75 for the BRA and 19 for the BRA+CCA [30]. Scores for the Regal Demoiselle and lionfishes (*Pterois miles* and *P. volitans*), known invaders [13], were also used to evaluate the relative risk of the remaining assessed pomacentrids.

3. Results

The bioprofiles showed that the damselfishes assessed in this study are small-bodied (<150 mm total length [TL]) tropical to subtropical fishes and commonly associated with coral reefs and other hard structures. Clown Anemonefish and Orange Clownfish are obligate sea anemone associates, and the other species are normally associated with specific types of corals outside of captivity. Aggression in nest and territory defense is most directed towards conspecifics, though other damselfishes and herbivorous reef fishes may also receive aggression. Few reports of damselfishes have been recorded outside of captivity anywhere, including in the risk assessment area, despite high trade volume. Only a single species, Regal Demoiselle, has established a non-native population, though this overlaps with the risk assessment area. Few potential impacts of this group are noted, though authors have speculated on the potential impacts of Regal Demoiselle on native Brown Chromis *Azurina multilineata* (Guuichenot, 1853), an ecologically similar species, in the

GOM. Biotic resistance from the large, diverse native damselfish fauna may limit the success of non-native damselfishes, though this has not been studied.

Regal Demoiselle scored considerably higher than other species, having the highest mean BRA score (17), individual BRA score (20), mean BRA+CCA score (15), and individual BRA+CCA score (16; Figure 1). This species, already established in marine waters of Florida, was the only species identified as a hazard in the present study. The lowest scores were associated with Spiny Chromis Damselfish. This species had the lowest mean BRA score (−8.5), individual BRA score (−10), mean BRA+CCA score (−7.5), and individual BRA+CCA score (−7).

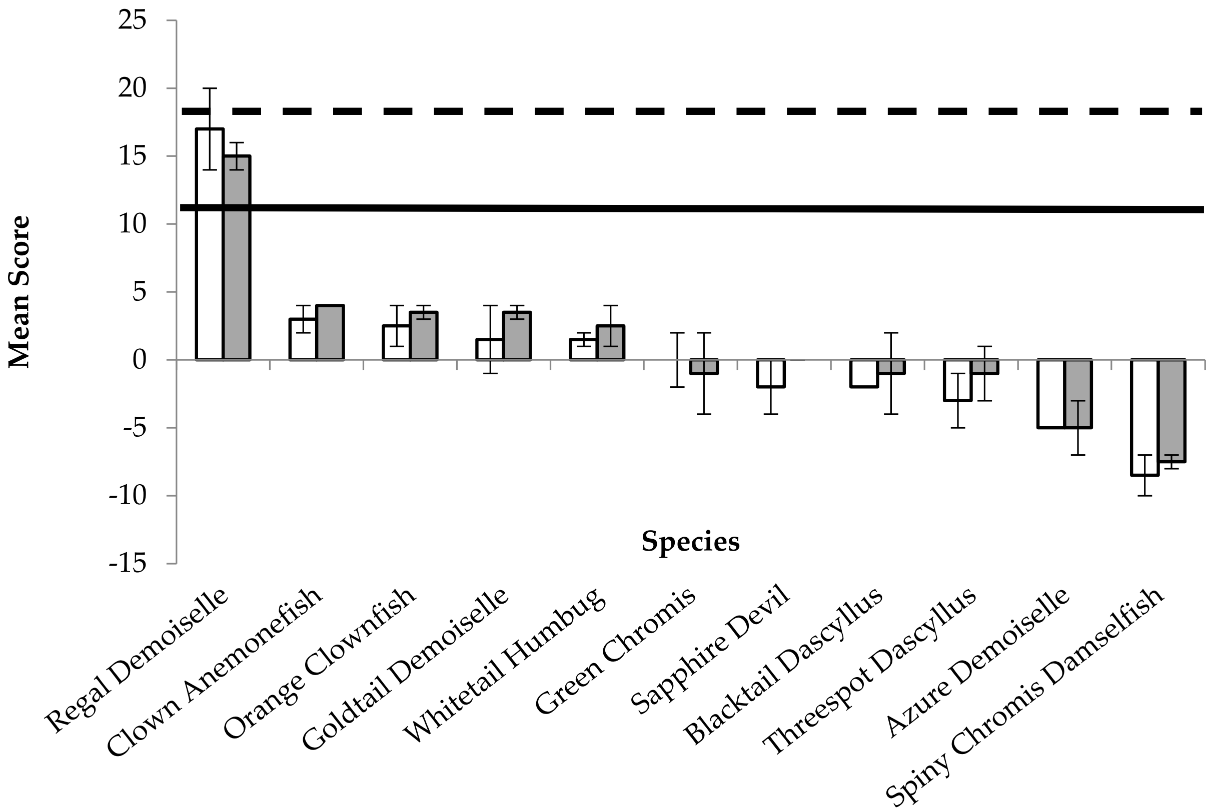

Figure 1. Results of AS-ISK assessments for 11 pomacentrid species, including the Basic Risk Assessment (BRA, open columns) and the BRA+Climate Change Assessment (BRA+CCA, gray columns). Error bars represent the maximum and minimum values for individual assessors. The dark horizontal line represents the global marine fish high-risk threshold of 12.75 (BRA), and the dashed horizontal line represents the global marine fish high-risk threshold of 19 (BRA+CCA; [30]).

The mean BRA score of Regal Demoiselle placed it into the High category, whereas four species scored Medium and six species scored Low (Table 2). No species scored as High in the climate-adjusted score (BRA+CCA), whereas five scored as Medium and six as Low (Table 2). Mean scores for the remaining species were all much lower than for Regal Demoiselle, the next closest score (Clown Anemonefish) being <20% in relative magnitude (Figure 1). Scores adjusted for climate change (BRA+CCA) increased slightly over the BRA for eight species (mean = 1.4 points), stayed the same for one species, and decreased slightly (mean = 1.5 points) for two species (Table 2).

Table 2. Results of AS-ISK assessments of 11 species of pomacentrid. BRA = Basic Risk Assessment; CCA = Climate Change Assessment; CF = Certainty Factor (0.25–1.0). Risk category is based on a high-risk threshold of 12.75 for the BRA and 19 for the BRA+CCA. Low risk is categorized as a mean score of ≤0.

Species	Mean BRA	Δ BRA	CF_{BRA}	Risk Category (BRA)	Mean BRA+CCA	Δ BRA+CCA	CF_{CCA}	$CF_{BRA+CCA}$	Risk Category (BRA+CCA)
Regal Demoiselle	17	6	0.69	High	15	2	0.56	0.68	Medium
Clown Anemonefish	3	2	0.65	Medium	4	0	0.56	0.64	Medium
Orange Clownfish	2.5	3	0.66	Medium	3.5	1	0.58	0.65	Medium
Goldtail Demoiselle	1.5	5	0.71	Medium	3.5	1	0.60	0.70	Medium
Whitetail Humbug	1.5	1	0.76	Medium	2.5	3	0.42	0.72	Medium
Green Chromis	0	4	0.75	Low	−1	6	0.52	0.73	Low
Sapphire Devil	−2	4	0.63	Low	0	0	0.44	0.61	Low
Blacktail Dascyllus	−2	0	0.73	Low	−1	6	0.40	0.69	Low
Threespot Dascyllus	−3	4	0.67	Low	−1	4	0.35	0.63	Low
Azure Demoiselle	−5	0	0.65	Low	−5	4	0.31	0.61	Low
Spiny Chromis Damselfish	−8.5	3	0.68	Low	−7.5	1	0.44	0.65	Low

Score partitioning for the AS-ISK assessments differed for the Regal Demoiselle compared to the remaining species (Figure 2). Mean values were all positive for this successful species except for climate change. Remaining species had mean values at or near zero for invasive elsewhere, undesirable (or persistence) traits, and resource exploitation and mean negative values for dispersal mechanisms and tolerance attributes (Figure 2).

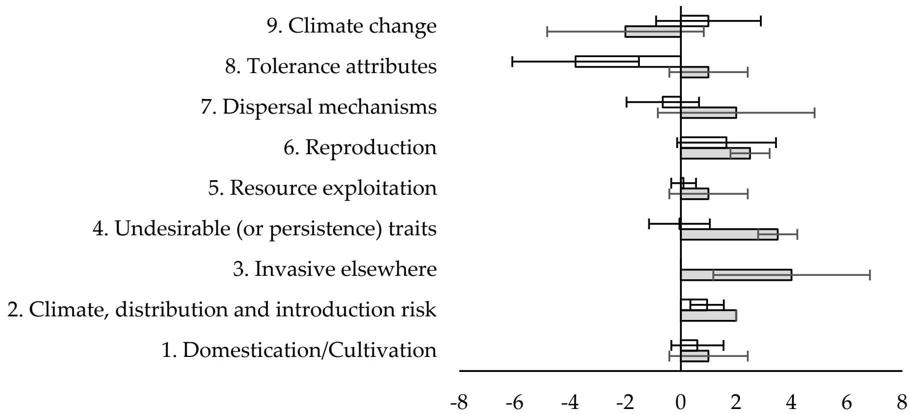

Figure 2. Mean (± SD) score partitioning for AS-ISK scoring categories of 10 pomacentrids in the marine ornamental fish trade (light bars) and Regal Demoiselle, a species established in the Gulf of Mexico (gray bars). Categories and corresponding question numbers are as follows: 1. Domestication/Cultivation (Q1–3); 2. Climate, distribution, and introduction risk (Q4–8); 3. Invasive elsewhere (Q9–13); 4. Undesirable (or persistence) traits (Q14–25); 5. Resource exploitation (Q26–27); 6. Reproduction (Q28–34); 7. Dispersal mechanisms (Q35–43); 8. Tolerance attributes (Q44–49); and 9. Climate change (Q50–55). The sum of categories 1 through 8 is the Basic Risk Assessment (BRA) score, and the sum of categories 1–9 is the BRA + Climate Change Assessment (CCA) score.

Certainty factor values ranged from 0.63 to 0.76 for the BRA (Table 1). Lower certainty was evident in the CCA, with CF ranging from 0.31 to 0.60. Lower certainty in the CCA resulted in lower CF values for the BRA+CCA than in the BRA. Highest certainty values were associated with Green Chromis (0.73) and Whitetail Humbug (0.72), lowest with Sapphire Devil (0.61) and Azure Demoiselle (0.61).

4. Discussion

The high-volume species we assessed scored as Low or Medium risk and currently do not represent hazards to marine waters and ecosystems of Florida and adjacent areas. Spiny Chromis Damselfish, a species in trade but at lower volumes, also scored Low risk. The only species assessed as High risk and therefore a potential hazard, Regal Demoiselle, is already established in the GOM where it has spread eastward into Florida waters [26,37]. However, most tropical species would be confined thermally to south and southeast Florida coastal waters from the Florida Keys to Cape Canaveral [38]. We thus conclude that despite high volume in the aquarium trade, most pomacentrids represent relatively little risk of invasiveness.

Regal Demoiselle scored as High risk mainly due to invasion history, a prominent factor in AS-ISK scoring. Its success in the GOM shows that a damselfish can survive and establish in the region. However, there are no studies on the impacts of this species and little to suggest the presence of moderate to severe impacts where it is established [39,40]. Another difference in this species is that, although it is present in the marine aquarium fish trade, it is not one of the top imported fish in the USA [3]. The pathway of introduction in this case was the movement of this species, often in large numbers, on oil rigs and other oil machinery [28,37,41]. This level of propagule pressure seems difficult to match by hobbyist release. The introduction and establishment of Tessellated Blenny in the northern GOM and southern Florida coast, likely facilitated by structures and movements of the oil industry [42], suggest further evaluation of this pathway is warranted.

The evaluated damselfishes did not differ greatly in mean BRA scores (3 to -5). Inspection of the scoring suggests that variability came primarily from variation in climate match and environmental tolerances. Otherwise, most species had relatively few traits that tend to enhance invasiveness. Pomacentrids have parental care, a trait associated with success in the establishment of non-native freshwater fishes in Florida [43,44]. It is unclear if parental care is associated with success or failure in marine fishes in Florida. Lionfishes lack parental care, but the established damselfish and blenny have male guarding of eggs. Overall, the pomacentrids assessed in this study were unlikely to be hazards in Florida and even less so in coastal GOM states and southeastern states from Georgia to North Carolina.

Although Regal Demoiselle scored much higher than the other assessed pomacentrids (17 vs. $\leq$3 in the BRA), its score was considerably lower than Devil Firefish and Red Lionfish in the risk assessment area (34 BRA [13]). The two lionfish are wide-ranging and highly impactful invaders in the tropical western Atlantic [45,46]; whereas the pomacentrid, though spreading, contrasts greatly by lacking substantial and well-documented impacts [39,40]. Differences in overall scores come from differences in answers to questions that link ultimately to performance of invasives in the field.

Certainty was lower for the CCA questions relative to BRA questions, with small effects on overall certainty (Table 1). Climate change has considerable uncertainty with experts producing scenarios of various levels of CO2 emissions and forecasting models with often widely ranging predictions [30]. Therefore, answering climate change-related questions in AS-ISK will reflect this uncertainty [30]. In general, there was agreement among assessors in the potential for larger areas of Florida's coastal waters to be vulnerable to establishment by the more tropical species in the future, though the impacts were not necessarily viewed as increasing. The outcome was that the BRA+CCA scores for 72% of species increased slightly (mean = 1.5 points) over BRA scores. Increasing scores due to climate change is a common phenomenon in AS-ISK assessments [30], often reflecting anticipated increased range, abundance, and impact associated with poleward movements of species [47] (see also [48]). Nevertheless, the complexity of the climate system, especially expected variability and anomalies, suggests that not all non-native species will increase in range or impact [49].

Despite high import volumes and presumably high propagule pressure, non-native damselfishes are not commonly reported in coastal marine waters of Florida, other southeastern US states, or in adjacent US federal waters. Besides Regal Demoiselle, four species of non-native damselfishes have records from the non-captive environment in Florida. In 2017, four or five Spiny Chromis Damselfish were observed and photographed in the Miami Beach Marina, Miami-Dade County, with two individuals removed subsequently [26]. A single Clown Anemonefish was removed from Fred Howard Park, Pinellas County, in 2018 [26]. A single Whitetail Humbug was removed from Palm Beach County in 2009 and two individuals were observed in the Miami Beach Marina, Miami-Dade County, in 2017 [26]. In 2006, a single Threespot Dascyllus was observed on a reef off Palm Beach County [26]. None of these species are known to be established in Florida waters, though multiple sightings of two species in the Miami Beach Marina is a cause for concern and warrants monitoring. Outside of Florida, the only non-native damselfish reported from Texas to North Carolina is Regal Demoiselle [26].

A considerable amount is known about pomacentrid basic biology and requirements due to their popularity as marine aquarium fishes and to field studies of this highly accessible group (i.e., usually visible and easily observed in reef and nearshore habitats). Conversely, almost nothing is known about them as invasive species. Lionfishes had a different pattern of information availability wherein aquarium knowledge of Red Lionfish was likewise considerable, but field studies of lionfishes were few [12]. The literature on Devil Firefish and Red Lionfish drastically increased following their invasion of the tropical western Atlantic Ocean, though information on other Lionfish species was scarce [12]. Lack of information on the biology and ecology of many marine fish groups makes risk assessment difficult. Further, few marine fishes have established non-native populations in the tropical western Atlantic and many other marine areas [50], hampering the calibration and testing of risk assessment tools [30,51]. However, non-native marine fishes are accumulating in some world regions such as the eastern Mediterranean Sea basin, allowing for regional [52] and general calibration by marine spatial and climate zones [30]. Addressing knowledge gaps would improve the evaluation of risk of this important fish family as well as marine fishes in general.

Besides establishment, impact is a key factor in invasiveness. So far, no particularly impactful non-native pomacentrids are known. This may be due to a scarcity of established species or due to traits of the species and environment. Pomacentrids are not within the trophic guild of known impactful marine fishes, those being predatory and affecting a variety of reef fishes (e.g., [46]). Until more is known about the types of effects that pomacentrids would have on biodiversity, ecosystem function or services, or economic activity, it is difficult to envision that these species are high-impact invaders. A remedy to this would be to study Regal Demoiselle in the GOM and determine if it is having important impacts where it is established (Table 2). Information on the interactions of native pomacentrids and their effects on fish and invertebrate communities and ecosystems in Florida (e.g., [53,54]) would better inform risk assessment. Further, additional evaluation of the marine ornamental pathway is needed to identify candidates for risk screening. Clearly, the large number of species in trade indicates that more species should be assessed to better capture the range of risk represented by the aquarium trade and other pathways (Table 2).

Horizon scans evaluate large numbers of species with a simple pre-screen and expert opinion but have, to date, required considerable numbers of assessors and commiserate levels of funding ([17]; J.E. Hill and Q.M. Tuckett's personal observations). Other ways that have been used by agencies to select species for initial evaluations include stakeholder or internal petition (formal or informal) and following the practice of other agencies, but usually these are ad hoc initiatives. Few agencies have systematic ways of choosing species for scrutiny of risks. Agencies could improve detection and exclusion of potentially invasive species by more proactive screening [55]. As noted, a useful approach evaluates pathways for genera, families, or functional groups with known invasives (invasion history) and significant trade (propagule pressure), two of the three most consistent predictors of invasion success [56]. The process would then screen the species in the group, perhaps focusing on the most important species in the pathway if too numerous for a single study; either way, known invasives would be screened for comparison [13]. This process would offer a narrower coverage than horizon scanning yet provide a more thorough screen for species likely to be released and have a phylogenetic connection with known invasives.

Management Recommendations

The overall low scores of pomacentrids in trade suggest that few specific, new management actions are needed for this group. We recommend:

- Educating the marine aquarium hobbyist about releasing aquarium fish, including partnering with Land Grant and Sea Grant institutions, public aquaria, museums, zoological centers, and other organizations to multiply and coordinate efforts;
- Maintaining and promoting websites and applications for reporting non-native species, including non-native pomacentrids and other marine aquarium species;
- Monitoring coastal waters, especially known hotspot bridges, jetties, and reefs for released aquarium fishes (EDRR);
- Conducting removals of non-native pomacentrids or other marine aquarium species when detected (EDRR);
- Updating screens and assessments as new data of importance become available (e.g., new species establish).

5. Conclusions

Focusing on priority pathways with known invaders can aid managers in choosing species for application of scarce risk assessment resources. This approach helped us select damselfishes, a group with an established species and other reported species within the risk assessment area, and further amongst the highest-volume species in the marine ornamental trade, a priority pathway. No additional species were identified as hazards, thus implementation of new management actions for this group is not pressing. Although narrower in focus than horizon scanning, we evaluated species representing about 40% by volume of the USA marine ornamental fish imports. This method can be used across taxa and pathways to better inform invasive species management.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes8050266/s1, Table S1: AS-ISK.

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Appendix A

Box A1. Definitions of risk analysis terminology, description of risk screening tools, and processes for choosing species for analysis.

The Society for Risk Analysis (SRA, https://www.sra.org/; accessed on 29 March 2023) provides definitions and guidance concerning terminology and procedures of risk analysis. Understanding these concepts is vital to the completion of high-quality risk-based products and their proper use in management. The SRA definitions and concepts are generic in nature, covering the range of fields using risk analysis [57]; the definitions and concepts related here have been modified slightly as is common across fields to specifically capture the appropriate application to, in this case, invasive species risk analysis.

Hazard versus risk—These terms are often used incorrectly as synonyms. Many screening tools identify hazards rather than relate risk (see below); confusion over this point may lead to management decisions using only preliminary information about the hazard rather than specific information concerning risk.

- Hazard—A risk source related to harm. Anything that can cause harm;
- Risk—A future activity or occurrence with potential negative consequences; the probability of an event occurring and the severity of the consequences.

With risk analysis for potentially invasive species, the non-native species/organism is a possible hazard in that it might cause harm. A potentially invasive species' risk relates to its introduction, establishment, and spread (the event occurring) and the impacts that occur (the consequences of the event).

Hazard identification versus risk assessment—Just as hazard and risk are different, hazard identification and risk assessment are distinct activities with different purposes.

- Hazard identification—A process whereby hazards are distinguished from non-hazards; determination of whether the non-native species of interest is likely to cause harm;
- Risk assessment—A systematic process to comprehend the nature of risk, and express and evaluate risk; estimation of the probability that a non-native species will be introduced, established, and spread; and evaluation of the impacts of the species in a region of interest (i.e., risk assessment area).

Hazard identification is an early step in risk analysis and is used to discriminate what species are likely hazards from likely non-hazards. Evaluation of species with a low likelihood of becoming a hazard is generally terminated at this stage. An effective hazard identification tool, often described for invasive species as rapid screens or screening tools, will categorize most risky species as a hazard or potential hazard. These are the species that require additional assessment to provide information for management. Risk assessment can be used with any species, hazard or not, but eliminating non-hazards from further analysis saves scarce resources (money, time, human capital).

Hazard identification tools—Many common risk screening tools are most properly used for hazard identification. The many derivatives of the Australian Weed Risk Assessment (WRA [58]), at least in their simple forms, distinguish potential hazards from non-hazards rather than delve deeply into estimates of risk despite outputs in the form of risk levels (i.e., low, medium, or high risk). This includes WRA-derivatives for other taxa such as the Fish Invasiveness Screening Kit (FISK [33,35,59]), Aquatic Species Invasiveness Screening Kit (AS-ISK [29,30]), and Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK [51]). These screens are among the more complex hazard identification tools, incorporating a wide range of data in the analysis [60,61] and having numerous scoring calibrations across different spatial scales and climates [30,33,51]. In the United States federal government, the Ecological Risk Screening Summaries (ERSS) tool is a simple hazard analysis based on invasion history and climate match [61–63]. These tools generally identify species that are potential hazards for further assessment.

Box A1. *Cont*.

Horizon scanning is a process for developing lists of potential hazards rather than hazard identification or risk assessment. The output is a simple multiplicative scoring system with arbitrary (i.e., non-calibrated) thresholds for categorization. The process creates a ranked list, either by raw score or scoring category (i.e., low, medium, and high risk), that is often limited to an arbitrary number of priority species. Species identified in horizon scanning most properly would be subjected to hazard identification (i.e., risk screening) prior to further evaluation. Those species further indicated as hazards would proceed to risk assessment as priority species; non-hazards would not proceed through any additional assessment.

Horizon scanning covers a broad range of species at a relatively shallow depth. The literature has considerable expression of the utility of this method for invasive species management; however, horizon scanning is not a true risk assessment and lacks much of the information needed for actionable management, especially information on risk evaluation, species benefits, and risk mitigation. Bayón and Vilà [64] recognized these limitations and followed up their horizon scan for non-native ornamental plants in Spain with a WRA-derivative as a hazard identification tool, noting the need for additional information prior to completing more comprehensive risk assessments. Matthews et al. [19] went considerably further in that they seek out various types of screens and assessments from the area of interest or climatically similar areas, harmonize the screens by assigning scores of Low = 1, Medium = 2, and High = 3, and calculate the average (aggregated risk score). This addition to horizon scanning entails considerable work if the assessments have not yet been conducted. If numerous assessments for a species exist, it might be simple to determine if the species is a hazard and then proceed to risk assessment. These and additional examples show that horizon scanning is a tool by which to determine species to further analyze in hazard identification and, potentially, in a comprehensive risk assessment. Horizon scanning clearly has strengths and valid uses but should not be mischaracterized or misused.

The method discussed in the present study, i.e., to focus on important species in important pathways that are closely related or functionally similar to known invaders, is likewise not a true hazard identification or risk assessment tool, being more akin to horizon scanning. However, the species identified, even if arbitrarily reduced in number for logistics' sake, are not subject to hazard identification until after being chosen, more similar to other risk screening/hazard identification tools. In fact, species chosen in this manner would then be subjected to a specific hazard identification tool, in this case, the AS-ISK. Given the outcome of the AS-ISK, especially with the additional information in the bioprofile, a species can be accurately categorized as a hazard or non-hazard. These species can then be prioritized and subjected to additional risk assessment to provide actionable information for risk management.

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