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Short-Term and Long-Term Predictions: Is the Green Crab *Carcinus maenas* a Threat to Antarctica and Southern South America under a Climate-Change Scenario?

Iván Vera-Escalona [1,2,*], Lucas H. Gimenez [1] and Antonio Brante [1,2]

[1] Facultad de Ciencias, Departamento de Ecología, Universidad Católica de la Santísima Concepción, Concepción 4090541, Chile
[2] Centro de Investigación en Biodiversidad y Ambientes Sustentables (CIBAS), Universidad Católica de la Santísima Concepción, Concepción 4090541, Chile
* Correspondence: ivera@ucsc.cl

Abstract: Non-native species can have profound implications on the survival of native ones. This is especially true for some invasive crabs, such as the green crab *Carcinus maenas*, a native species to the Northern Hemisphere that has been introduced into southern Argentina, from where it could expand through Argentina, Chile, and the Antarctic Peninsula. Hence, there is interest in forecasting changes in *C. maenas* habitat suitability through time to predict if potential future invasions might occur. Here, by using a Species Distribution Model (SDM) approach, we estimated the habitat suitability for *C. maenas* along southern South America and the Antarctic Peninsula under two future climate-change scenarios. Our results reveal that under current conditions, habitat suitability for *C. maenas* along the Antarctic Peninsula is null and very restricted in Argentina and Chile. Habitat suitability along the Antarctic Peninsula remained null in the short-term (30 years) and long-term future (80 years), despite the climate-change scenario considered. Surprisingly, when considering future conditions, habitat suitability along the coast of Argentina and Chile decreased and became nil for some currently occupied locations. Thus, the SDM results suggest that climate change could have a negative effect on the habitat suitability of *C. maenas* leading to potential local extinctions.

Keywords: invasive species; green crab; climate change

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1. Introduction

The successful introduction of non-native species in new regions of the world (e.g., via maritime transport) can cause a biological invasion, carrying negative impacts on native organisms and the landscape where they live [1]. Because of the potential impact of these invasive species on the maintenance of native biodiversity, habitats, and derived resources for humans, researchers have tried to detect potential invasive species before they expand into new regions of the world [2,3]. For this purpose, researchers have used different approaches, including physiological experiments, genomic studies, and Species Distribution Models (SDMs) to identify candidate invasive species and potential regions of the world where these species could be established [4]. Among these approaches, SDMs are key to forecast habitat suitability, especially under different climate scenarios [4–6].

Climate change, as a driver of shifts in environmental conditions worldwide, can have a wide array of consequences for the ecological patterns of species, especially for their geographic ranges [7]. When forecasting the future distribution range of a given species under a climate-change scenario, the results can vary among species [8]. The literature on biological invasions suggests that climate change can have a positive effect on invasive species, acting as a facilitator for the introduction of new non-native species and increasing the geographic range of extant ones [8,9]. However, a negative effect of climate change on invasive species is also plausible, leading to an unexpected outcome: the reduction in and disappearance of habitat suitability for extant invasive species [10]. Such outcomes (i.e., a contraction in the distribution range) have been documented for several terrestrial and freshwater species. For instance, Gallardo and Aldrige [11] found that the invasive crayfish *Pacifastacus leniusculutus* could experience a 32% decrease in its distribution range size by 2050 because of climate change. A similar pattern was found by Raghavan et al. [12] for the paralysis tick *Ixoded holocyclus* in parts of Australia. Along the same lines, Bradley and Wilcove [13] found that the plant cheatgrass *Bromus tectorum* will no longer be viable in the Western United States by 2100.

Non-native marine organisms have already arrived at the Antarctic coast, with different outcomes so far. For instance, remains of the algae *Durvillaea antarctica* have been found in the Antarctica territory, but no evidence exists of surviving individuals on the continent [14]. On the other hand, individuals of the mussel *Perumitylus purpuratus* have been found alive, presenting a major threat to Antarctic species [15]. This suggests that new studies addressing the potential arrival and likely survival of invasive species in Antarctica are needed, especially on a small scale.

One of the widest-spread invasive species in coastal environments worldwide, with great negative impacts on native fauna is the green crab *Carcinus maenas*. This littoral crab, likely native to the European East Atlantic, has experienced a rapid expansion outside its native region mediated by humans due to maritime transport during the last century [16]. Several sources have identified this species as a major threat, suggesting potential major disasters for native species and the habitat where they establish new populations along protected and semi-protected estuarine habitats [17,18]. *Carcinus maenas* is an opportunistic feeder, acting as a top predator in estuarine ecosystems, feeding on a variety of organisms, including mollusks, crabs, algae, insects, and small plants [17,19,20]. The green crab has rapidly invaded the Southern Hemisphere, including several patches along the coast of Argentina due to its tolerance to a wide range of salinities and temperatures [19,20]. This species presents a haemolymph–magnesium concentration (MgHL) in the range of 10–20 mM, similar to the values observed among organisms adapted to survive in cold waters near the poles [21,22]. Thus, the green crab could potentially join king crabs, an already established non-native species, on the list of invader crab species in the continental slope from the western Antarctic Peninsula [22]. Because of this, the green crab has been identified as a species of major concern that could potentially expand in the short term through cold regions of South American and Antarctica because of the increase in ship traffic connecting these regions [21,22]. Although studies on the extant habitat suitability of *C. maenas* in South America exist [22], no study has restricted the habitat distribution of the species to coastal regions to focus on the particularities of the future distribution of *C. maenas* under a climate-change scenario without a pre-assumption of a likely extended expansion. Furthermore, no study has recorded this species in other cold-water regions of South America outside of Argentina and Antarctica. Even more, models have revealed that at least in East Antarctica, this species does not have the habitat suitability required to survive during the next century, despite the climate-change scenario evaluated [23]. Nevertheless, this has not been evaluated yet for West Antarctica, especially in the Antarctic Peninsula. The Antarctic Peninsula is the northernmost and warmest region of Antarctica, with an active traffic of maritime transport that could facilitate the introduction of the species into Antarctica [24]. Therefore, it is important to evaluate habitat suitability along the coast of southern South America and the Antarctic Peninsula.

The evaluation of habitat suitability for invasive species has commonly been evaluated through Species Distribution Models (SDMs), using occurrences of species and climate change projections, which represent a useful, cost-effective tool for forecasting the species potential distributions [25]. For this purpose, the current distribution of a given species is correlated with environmental attributes, such as topology, geology, and climate variables, to detect suitable areas for its occurrence [26]. These attributes arranged along a gradient of proximal to distal predictors can give habitat suitability probabilities as a proxy of the potential establishment and survival of non-native species in new environments at present and in the future [27]. For future environmental conditions, SDMs use four different Representative Concentration Pathway (RCP) scenarios, with two of them, RCP 2.6 and RCP 8.5, representing extreme conditions. On one hand, RCP 2.6 is an optimistic scenario where CO_2 emissions decline from 2020 until reaching zero by 2100 with the compromise of all countries, maintaining global temperatures to increase below 2°C [28]. On the other hand, RCP 8.5 is a worst-case scenario where CO_2 will continue rising during the next decades and the global temperature will increase between 3 and 4 °C [29]. Both contrasting scenarios are still possible according to the 2019 Emissions Gas Report [30] and can produce changes not only in climate but also in the landscape. It is thus plausible that these scenarios will ultimately affect the habitat suitability of extant and potential invasive species. Considering that both scenarios are still conceivable, we created habitat suitability scenarios based on the Species Distribution Model (SDM) for the green crab *C. maenas* under current and future conditions in southern South America and the Antarctic Peninsula. With this in mind, we evaluated (i) whether *C. maenas* could expand along Argentina and nearby regions, including Chile and the Antarctic Peninsula and (ii) what could be the potential effects of climate change for *C. maenas* by 2050 and 2100 in terms of habitat expansion and contraction, considering different climate-change scenarios (RCP2.6, less severe increase in temperature and RCP8.5 most severe increase in temperature).

2. Materials and Methods

2.1. Occurrences

Geo-referenced occurrences of *C. maneas* were compiled from the Global Biodiversity Information Facility [31] and the Ocean Biodiversity Information System (OBIS, https://www.obis.org/, accessed in October 2021). We considered all occurrences, including both the native and non-native ranges, as global records can better describe the realized niche of invasive species [32]. We limited our occurrence records to those reported from 2000 to the present. We eliminated imprecise and duplicated points, and then we thinned our dataset to one per grid cell of predictors to avoid redundance or sampling biases (spThin package v0.2.0, [33]). The resulting dataset contained 1564 occurrences (see Figure S1, Supplementary Materials).

2.2. Environmental Predictors

Environmental data were obtained from Bio-ORACLE v2.1 [34,35] and MARSPEC [36] with a resolution of 5 arcmin that represents 0.08° or 9.2 km at the equator. These environmental layers have previously been applied to project potential distributions of coastal non-native species, including crabs [37–40]. Predictor selection was carried out based on biological relevance and pairwise correlation analyses to avoid collinearity among predictors (Table 1 and Figure S2).

We used three scenarios: current (average values from 2002 to 2014), short-term future (2040–2050), and long-term future (2090–2100). For future scenarios, we considered two Representative Concentration Pathway (RCP) projections. The RCP2.6 projection scenarios assumed the least severe change with an increase in temperature of 1 °C in 2050 and 2 °C in 2100 and an increase of 0.5 and 1 psu units for salinity. Conversely, the RCP8.5 scenarios presumed the most severe change with an increase in temperature of 1 °C in 2050 and almost 3 °C in 2100, and an increase of 1 and 1.5 psu units for the salinity, respectively. For more details of each IPCC scenario see Assis et al. [35].

Table 1. Summary of topological and environmental predictors selected based on biological relevance for *Carcinus maenas* and the scenarios considered in our study. Variables highlighted in **bold** are those selected after pairwise correlation analyses.

Environmental Predictor (Unit)	Present	Future	Source
Depth (m)	-	Same as present	MARSPEC
Distance to shore (km)	-	Same as present	
Mean seafloor temperature (°C)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	Bio-Oracle
Min seafloor temperature (°C)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	
Max seafloor temperature (°C)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	
Mean seafloor salinity (PSS)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	
Min seafloor salinity (PSS)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	
Max seafloor salinity (PSS)	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	
Mean surface primary productivity ($g \cdot m^{-3}$ day^{-1})	2000–2014	Same as present	
Mean seafloor current velocity (m^{-1})	2000–2014	RCP 2.6 and 8.5 for 2050 and 2010	

2.3. *Species Distribution Modeling: Calibration, Evaluation, and Projection*

We used the Maxent algorithm [41] and considered 10,000 random background points inside a bounding box delimited by the extension of the occurrences. We generated different models selecting five different feature-class combinations (L, LQ, H, LQH, and LQHP, where L = Linear, Q = Quadratic, H = Hinge, and P = Product; for more details about feature classes see [42]) and different regularization multipliers (ranging in a sequence from 1 to 10 with increments of 1). These settings create models with different complexities and permit statistical evaluations to find the most optimal settings. We calibrated the models with a cross-validation procedure using a random partition (random k-fold method, k = 5). This partitioning method generates k binds (or sets of occurrences) to train and test the resulting model. We selected our model based on the lowest Akaike information criterion value (AICc, [43]). Then, we evaluated the performance of our model with multiple criteria: the omission rate (OR, [41]), the significance of the partial Receiver Operating Characteristic curve (pROC, [44]), the Area Under the ROC (AUC, [41]), and the Boyce's index [45]. For a review of different evaluation procedures, see Zurell et al. [46] and Sillero et al. [47]. The AICc, omission rate, and AUC values were returned by Maxent. The partial ROC significance was calculated with the 'NicheToolBox' (NTBOX) package v0.4.6.0 [48]. The Boyce's index calculation was performed with the 'ecospat' package v3.2 [49].

Once we built the model for the current scenario, we projected it into each future scenario to see potential changes in the predicted distribution of *C. maenas*. To avoid potential extrapolation, we evaluated whether current and future environmental conditions were analog (i.e., comparable). For that, we used the multivariate environmental similarity surface analysis (MESS). MESS evaluates how similar a point is in relation to a set of reference points with respect to a set of predictive variables [50]. The MESS analysis was run using the 'NicheToolBox' package. This analysis ranges from negative to positive values, where positive values indicate analog areas and negative values indicate non-analog areas (i.e., at least one variable has a value outside the range of conditions in the reference area, which in this study is the current scenario). Overall, we did not find large extrapolation areas regardless of the future condition considered (Figure S3).

All the projections from the model are at a logistic, continuous scale. All analyses mentioned were performed in R [50], and all maps were generated in QGIS software v.3.16 [51]. For further details on results from the modeling procedure, see the Supplementary Materials, including Model selection (Figure S4), response curves (Figure S5), predictors importance (Table S1), and a summary of performance evaluation of the selected model (Table S2).

3. Results

3.1. Contemporary Habitat Suitability

Contemporary habitat suitability for *C. maenas* in southern South America and the Antarctic Peninsula revealed an extremely narrow distribution, restricted by temperature, depth, and distance to the coast (Table S1). The highest suitability values were found for the northern Atlantic coast in Argentina between 38 and 50° S (Buenos Aires, Río Negro, Chubut, and Santa Cruz), decreasing to the south (Figure 1). Our model predicted habitat suitability ranging from 0.2 to 0.8, with the highest values in the northern regions of Argentina but very restricted between 43 and 45° S where the species has been reported on the coast (Figure 2A and Table S3). High habitat suitability (0.8) for *C. maenas* on the Pacific coast of Chile was greatly restricted to two regions no larger than 5–10 km on southern Chiloe Island (43° S) and Tierra del Fuego (52° S, Figure 1).

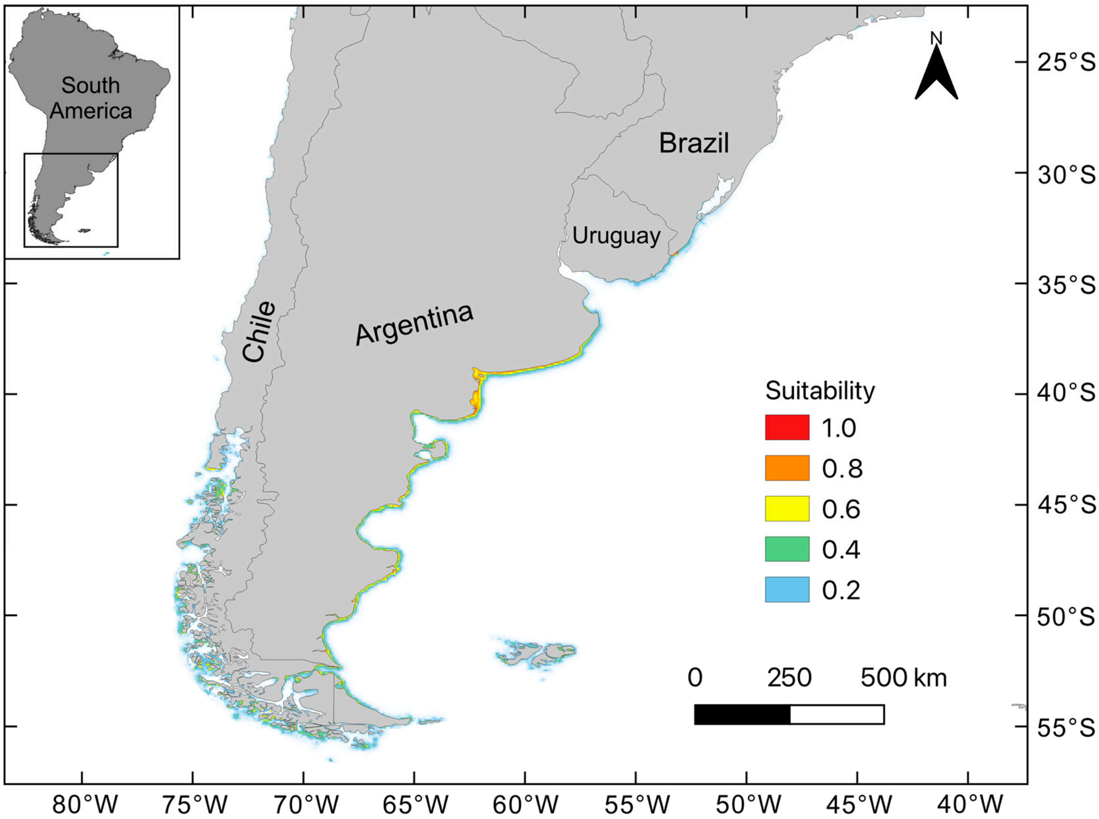

Figure 1. Potential distribution of *Carcinus maenas* on the coast of South America under a current climate scenario.

For the Antarctic Peninsula, the results of the SDM approach reveal that habitat suitability for *C. maenas* along the coast of the Antarctic Peninsula was zero (Figure S7), suggesting a lack of favorable environmental conditions for *C. maenas* to survive in this continent despite the simulated conditions (including and removing the presence of glaciers).

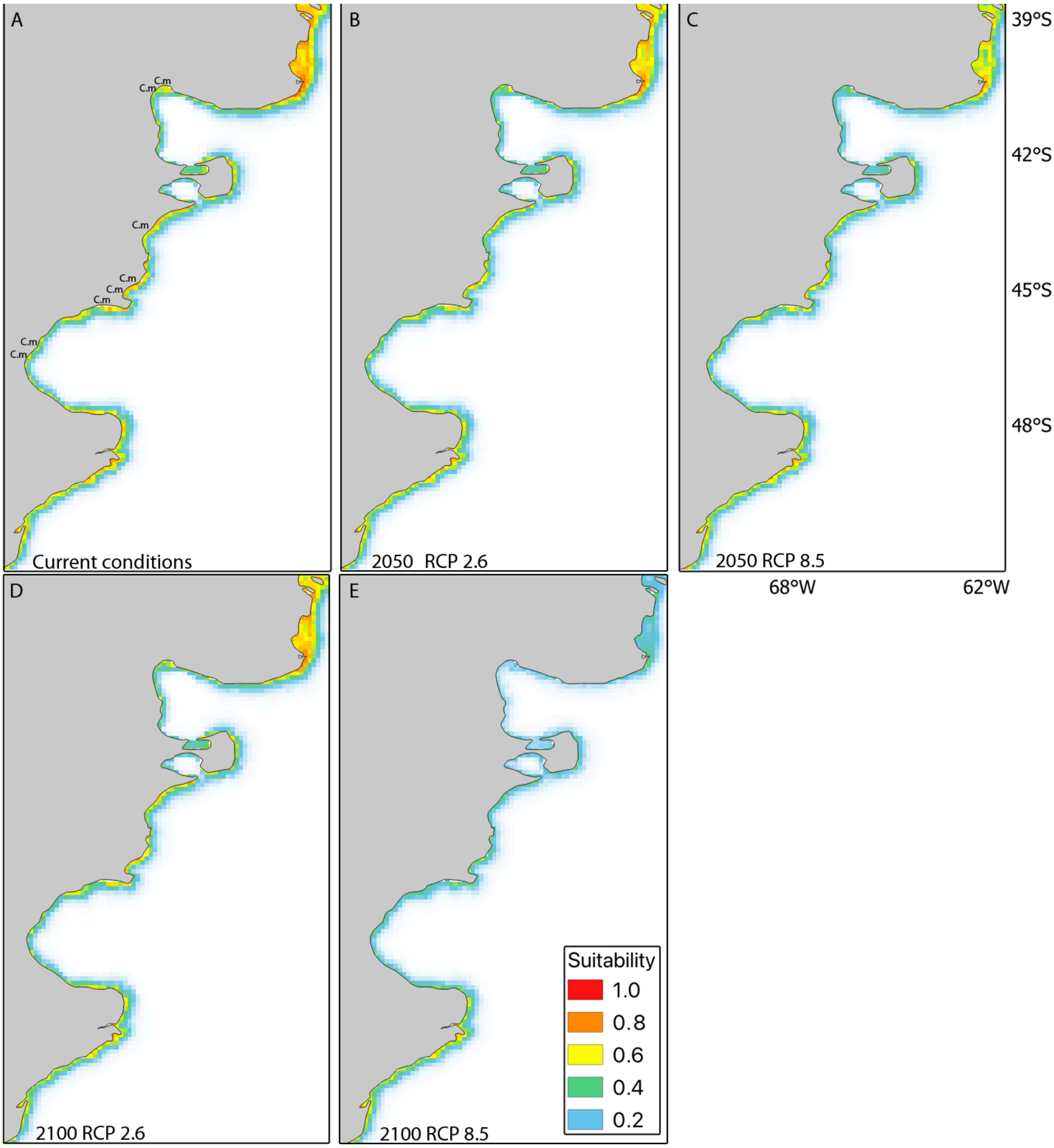

Figure 2. Comparisons among potential distributions of *Carcinus maenas* on the coast of Argentina under different future climate-change scenarios: current conditions (**A**), year 2050 RCP 2.6 (**B**), year 2050 RCP 8.5 (**C**), year 2100 RCP 2.6 (**D**), and year 2100 RCP 8.5 (**E**). C.m = locations where *C. maenas* were found (see Table S3 in the Supplementary Materials).

3.2. Short-Term Habitat Suitability (2050) and Long-Term Habitat Suitability (2100) under RCP2.6 and RCP8.5

Habitat suitability for *C. maenas* by 2050 under the RCP 2.6 scenario tends to decrease along the coast of Argentina from 42° S, a pattern that also occurs along the coast of Chile (Figure S6). Thus, most regions with a contemporary habitat suitability ranging from 0.6 to 0.8 become less suitable for *C. maenas*, with values ranging from 0.2 to 0.6 (Figure 2B). This pattern is observed throughout the localities where *C. maenas* can be found nowadays (Figure 2A). Under the RCP 8.5 scenario, habitat suitability for *C. maenas* in

Argentina and Chile considerably decreased from contemporary and RCP 2.6 predictions, with habitat suitability for *C. maenas* decreasing down to 0.2 in regions with previous values of 0.6–0.8 (Figure 2C). This decrease in habitat suitability becomes more evident by 2010 under the RCP 2.6 and RCP 8.5 scenarios (Figures 2D,E and S6). This is especially true by 2100 under the RCP 8.5 scenario, where habitat suitability for *C. maenas* along the coast of Argentina decreases to 0.2 (Figure 2E).

Despite the climate scenarios simulated (RCP 2.6 and RCP 2.8), no habitat suitability was found for *C. maenas* in the Antarctic Peninsula by 2100 (Figure S7).

4. Discussion

The introduction of non-native crabs has been identified as one the most concerning threats to native species worldwide, including Antarctica. Introduced crabs can potentially consume, compete, and even eradicate native species [22,52–54]. Due to the likely impact of crabs on the Antarctic coast, there is an interest to identify using a finer scale what could occur with species in the short-term and long-term future. Here, we used an SDM approach to estimate the habitat suitability for the green crab *C. maenas* along southern South America and Antarctica, using different climate-change scenarios (RCP 2.6 and RCP 8.5). We aimed to identify potential range expansions from its current distribution based on habitat suitability (South Argentina). Our results reveal that contrary to what we expected, an extreme effect of climate change (RCP 8.5) by 2050–2100 could negatively affect the potential distribution of *C. maenas* in South America by reducing its habitat suitability. We also found that there is no habitat suitability for *C. maenas* along the Antarctic Peninsula, despite the scenario and period simulated.

4.1. Crabs in Antarctica

A previous study on the likeliness of invasive species along the Australian Antarctic research stations in East Antarctica and two subantarctic islands using a gradient-boosted machine-learning approach found no habitat suitability for *C. maenas* neither in the present nor in the future [23]. Here, we complemented this analysis by assessing whether *C. maenas* could survive in the Antarctic Peninsula in Western Antarctica. In summary, despite being the northernmost part of Antarctica and a region highly connected with Argentina through maritime traffic and rafting events, the Antarctic Peninsula does not present habitat suitability for *C. maenas*, and therefore the establishment of this species is unlikely in this region in the short- and long-term future. Our findings suggest that the lack of habitat suitability for *C. maenas* in the Antarctic Peninsula occurs because the temperature, depth, and distance to the shoreline needed to allow the survival of the species would not be adequate for the survival of the species, despite the climate-change scenario considered.

This conclusion and the conclusions from Holland et al. [23] contrast with physiological studies suggesting that *C. maenas* could survive in Antarctica in the short-term if the temperature increased, because this species can regulate magnesium ion concentrations in the hemolymph (MgHL), and thus survive in polar water as is the case with the king crab in the Antarctic continental shelf [21,22]. Nevertheless, because temperature is not the only factor increasing habitat suitability, this survival scenario suggested by physiological studies might not occur. These results are in the line with a recent study of another potentially invasive crab on the coast of the Antarctic Peninsula, *Halicarcinus planatus*, for which new evidence suggests that, contrary to previous studies, the species could not survive in the Antarctic Peninsula in the short term [38]. Thus, it is unlikely that marine shoreline crabs, such as *C. maenas,* could survive in Antarctica, even if some individuals reach the continent. Therefore, the fear that this species could reach Antarctica and produce one of the largest declines in Antarctic coastal native species, as suggested by previous studies [22,55], should be lessened. These results confirm previous studies suggesting that *C. maenas* distribution and likely expansion are limited by temperature as lower temperatures limit *C. maenas* reproduction and increase adult mortality [56,57].

4.2. Green Crab in Southern South America: Current Potential Distribution and Predictions by 2050 and 2100

Here, we observe that our SDM scenarios for the current potential distribution of *C. maenas* along South America revealed a moderate to high habitat suitability (Figure 1) in regions where the species has been introduced and established (e.g., Golfo Nuevo, Camarones, Golfo San Jorge, and Golfo San Matías, Figure 2A). Our findings reveal that habitat suitability for this species is restricted and not continuous. Interestingly, habitat suitability was high in southern Argentina and Uruguay, but low in other nearby but colder regions, such as the Malvinas/Falkland Islands and Chile. This result refutes our expectations that *C. maenas* could be more prone to find habitat suitability in southern South America outside Argentina. In Chile, habitat suitability was moderate to high in two regions only, Chiloe Island (43° S) and Tierra del Fuego (52° S). This low habitat suitability agrees with observations made in Chile where *C. maenas* has not been detected, despite being a country with over 50 non-native marine species reported [58]. Thus, the restricted distribution of *C. maenas* in South America to some regions of Argentina seems to reflect a patchy rather than an extended distribution [59,60], with little expansion potential.

Short-term and long-term habitat suitability for *C. maenas* (2050–2100) under an RCP 2.6 scenario drastically declines along the southernmost coast of Argentina (42° S, Figure 2B,D), a similar trend observed along the coast of Chile (Figure S6). Habitat suitability north of 42° S in Argentina and Uruguay remains similar under this scenario (Figure 2B,D). The observed general trend of habitat suitability declining for *C. maenas* along the coast of South America is higher when considering an RCP 8.5 scenario. The area where habitat suitability decreases the most coincides with the region where the Brazilian current and the Malvinas/Falkland current converge along the southwest South Atlantic Ocean, a region that is expected to exhibit an increase of 3–4 °C in temperature by 2100 [61,62]. This increase in temperature could negatively affect *C. maenas*, because females require temperatures at or below 18 °C [63], and therefore an expected increase in sea temperature of 3–4 °C along the coast of Argentina could negatively affect the suitability and survival of the species. This temperature susceptibility of *C. maenas* together with the results of habitat suitability from our models could explain why introductions of the species have not been successful in the long term in warmer regions of South America (e.g., Brazil, [63]). These results also support our conclusion that despite a likely expansion of *C. maenas* during the next years, an increase in the ocean temperature in the long term due to climate change could negatively affect this invasive species.

4.3. Species Distribution Models and Invasive Species

The power of Species Distribution Models (SDMs) forecasting the invasiveness potential of species under different climate-change scenarios has led authors to suggest that this approach is an important tool for avoiding the establishment and expansion of invasive species [64–67]. In general, SDM studies suggest that the consequences of climate change could be positive for invasive species [10,68]. However, a few studies suggest a negative effect of climate change on the expansion of invasive and potentially invasive species [69,70]. For instance, Bradley et al. [71]. found that the invasive plant cheatgrass *Bromus tectorum* will be negatively affected by climate change by 2100 and that its survival could be jeopardized in the Western United States. A similar effect has been predicted for two invasive tick species, *Ixodes holocyclus* and *Ixodes cornuatus* from Western Australia, and also for the green spurge *Euphorbia esula* and the giant hogweed *Heracleum mantegazzianum* for which habitat suitability will decrease during the next decades as a consequence of climate change [71–73]. Here we present, to the best of our knowledge, the first article using an SDM approach suggesting that an invasive marine species habitat suitability could shrink and potentially disappear in an invaded region. Thus, our SDMs suggest a certain paradox on the effects of climate change and marine invasive species, suggesting that climate change could have a negative effect on some invasive species.

4.4. Study Limitations

Our study using an SDM approach for forecasting the potential habitat suitability for *C. maenas* in South America and the Antarctic Peninsula included distance to the shoreline as a variable. Thus, our models considered that this species inhabits areas from the shoreline to the lower limit where *C. maenas* larvae could be found [74]. By doing so, we expected that these results could reflect a more accurate range of potential habitats for *C. maenas* than those observed by previous studies [75]. A side problem with this methodology is that grids reflecting habitat suitability become more restricted, and when continental shelf occupies most of the grid, it becomes more visually challenging to distinguish regions where higher habitat suitability occurs. Nevertheless, the variables used in our models can reflect the biological conditions where the crab lives, and thus limitations are mostly visual rather than biological.

Another limitation of our study would be some likely over-interpretation as SDM models can only infer potential habitat suitability and not evolution. Species evolve, and thus it is likely that *C. maenas* could potentially adapt to the new conditions of the environment under different climate-change scenarios. Invasive species can in fact experience strong selection after being introduced in new regions of the world [76]. For instance, Tepolt et al. [77] found that *C. maenas* individuals from an invaded region in the northern Pacific presented loci indicating temperature tolerance, and thus despite the SDM predictions, evolution could play a major role in the survival of the species. Furthermore, aquatic species, such as *C. maenas,* can present other attributes not included in models and not considered by previous authors that could help the species to survive in colder environments. For instance, a recent study suggests that, in addition to low-temperature resistance, small-sized generalist organisms with active dispersal are more prone to survive in invaded colder waters [78]. All these traits can be found in *C. maenas* and therefore could allow the species to survive in southernmost parts of Argentina and Chile and in Antarctica.

5. Conclusions

In this article, we present two main conclusions when forecasting what could occur with the crab *C. maenas* during this century, at least as shown by SDMs. The first conclusion is that the chances of *C. maenas* establishing populations along the Antarctic Peninsula, which is the warmest place in Antarctica [79], are unlikely. The second conclusion of our study is that a large expansion of *C. maenas* along southern South America is unlikely, despite the climate-change scenario considered.

These results are important for the conservation of native species preyed on by *C. maenas* because they suggest that efforts on the removal of the species in invaded regions could have a positive effect in the short and long terms. This is especially true when considering that under a scenario where CO_2 emissions continue to increase and the worst climate change projections are finally reached, *C. maenas* could be naturally controlled due to the disappearance of the suitability of its habitat.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15050632/s1, Figure S1: Current distribution of *Carcinus maenas* (2000–present); Figure S2: Correlation analysis to select predictors to model the potential distribution of *Carcinus maenas*; Figure S3: Environmental analogy between the current and each future climate-change scenario; Figure S4: Model selection for the species distribution of *Carcinus maenas*; Figure S5: Response curves of *Carcinus maenas*; Figure S6: Species Distribution Models for the green crab *Carcinus maenas* along the coast of southern South America; Figure S7: Species Distribution Models for the green crab *Carcinus maenas* along the Antarctic Peninsula; Table S1: Summary of percent contribution and permutation importance of each predictor; Table S2: Summary of the evaluation for the selected model for the green crab *Carcinus maenas*; Table S3: Location, latitude, and references of records of *Carcinus maenas* along the coast of Argentina [80–82].

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