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Recruitment and habitat ecology of juvenile mangrove red snapper (*Lutjanus argentimaculatus* Forsskal, 1775) in central Vietnam

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Abstract
Mangrove Red Snapper has been a valuable aquaculture fish in Vietnam, however, its aquaculture mostly depends on fingerlings collected from the wild. There is no ecological study conducted for this species in Vietnam, although its resource is seriously threatened by increased fishing and habitat depression. In this study, we examined the recruitment and habitat ecology of juveniles. We found that there was only one main period of the recruitment occurring in July to August, with a large number of <3cm fish caught. Most juveniles were associated with rocky habitats in brackish water areas that comprised a wide range of natural food prey, especially dominance of shrimps. We also found that use of fishing gears was related to movement of juvenile fish during the recruitment. Here, we have shown important information on ecological aspects of juvenile Mangrove Red Snapper in central Vietnam that would be useful for next studies tending to maintain wild fish resource and support aquaculture as well.

Keywords: Habitat, recruitment, juveniles, mangrove red snapper

1. Introduction
Mangrove Red Snapper is a preferred fish species for aquaculture in South East Asia, including Vietnam. However, mariculture of *L. argentimaculatus* still depends on the wild juvenile resource that is seasonal, variable, and probably unsustainable [1]. Moreover, juveniles of Mangrove Red Snapper are known to recruit to coastal areas and estuaries [2, 3], however, the practice of fishing for juveniles to supply the aquaculture industry, coupled with the apparent loss of suitable nursery grounds in many coastal areas have seriously affected the sustainability of their populations [4]. Thus, knowledge of the recruitment as well as habitat characteristics critical to the recruitment process is urgently needed, both to focus management of coastal areas, and to enhance artificial culture of this species to reduce harvest pressure on stocks of wild juveniles.
In Vietnam, Mangrove Red Snapper aquaculture mostly depends on fingerlings collected from the wild, even though induced spawning of *L. argentimaculatus* is a relatively well-known and straightforward procedure [2, 5, 6]. This means that increased juvenile fishing is causing serious pressure on the wild fish resource. Interviews with older fishermen and mariculturists indicate that previous generations of fishermen were able to harvest these fish throughout coastal Vietnam. However, the majority of wild juveniles *L. argentimaculatus* for mariculture in coastal Vietnam are captured from two central provinces, where coastal lagoons fed by rivers are associated with mangrove forest. It is likely that degradation of coastal ecosystems, including the ubiquitous conversion of mangroves for shrimp aquaculture throughout Southeast Asia [7], and losses of critical nursery habitats have contributed to the depauperisation of the Mangrove Red Snapper populations.
Unfortunately, the key attributes of these critical habitats are largely unknown. Local fishermen are extremely familiar with patterns of recruitment and habitat use by these fish, but, until now there has been no ecological study on recruitment or distribution of juvenile Mangrove Red Snapper in Vietnam. Although this is a valuable aquaculture fish, and although the techniques for spawning and hatching of larvae are well-known, little is known of the manner in which critical habitats influence the development and survivorship of the settled juveniles. Nor is it known how these key habitat characteristics influence the perceived viability advantage of wild-caught juveniles over hatchery-raised fry. Therefore, this study was conducted to examine the recruitment and habitat ecology of this fish species.

2. Materials and Methods

2.1. Study sites

This study was carried out in two provinces (Thua Thien Hue and Binh Dinh) in the north and south central Vietnam (Figure 1). Field surveys were undertaken from July to November, 2015 to examine natural recruitment habitats in the two provinces, where juvenile Mangrove Red Snapper and other fish such as groupers or rabbitfish are harvested in large numbers for the aquaculture industry. Both provinces have river-fed coastal lagoons connected to the sea; "Tam Giang-Cau Hai" in Thua Thien Hue province is the largest lagoon system in Vietnam, with area of 21,600ha. Binh Dinh province also has several lagoons, especially "Thi Nai" lagoon, with an area of over 5,000ha.

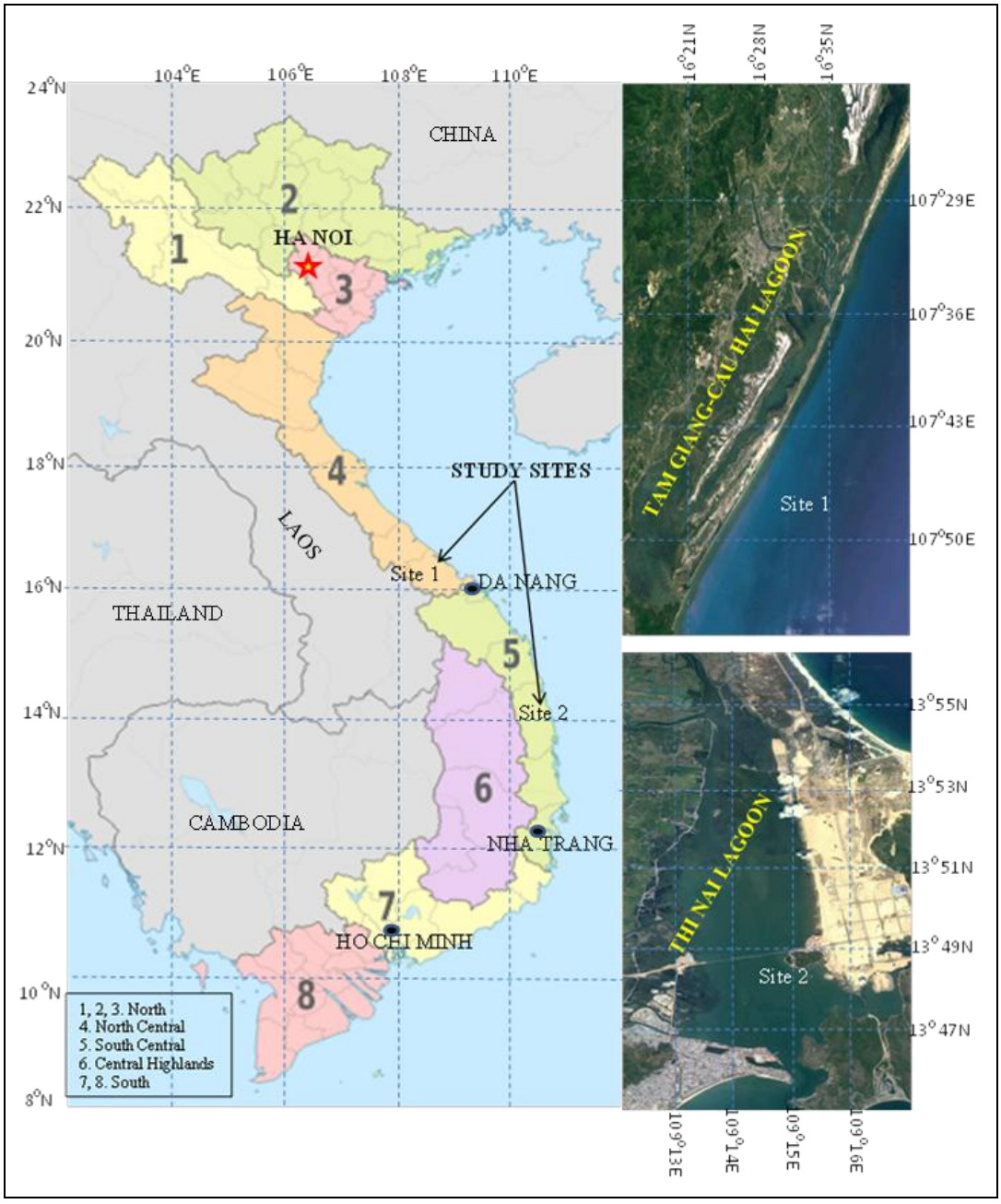

Fig 1: Study sites (Site 1: "Tam Giang-Cau Hai" in Thua Thien Hue province; Site 2: "Thi Nai" lagoon in Binh Dinh province).

2.2. The data collection and analysis

Interviews with local fishermen were undertaken at study locations using a standardized questionnaire to collect information related to recruitment, habitat and fishing of juveniles Mangrove Red Snapper in the period from 2005 to 2015. A total of 73 fishermen (of whom 48 were in Thua Thien Hue and 25 in Binh Dinh) experienced in catching, rearing, or trading juveniles Mangrove Red Snapper were interviewed during study period.

Field surveys were made to record details of habitat as well as directly observe fishing methods. By applying transects, details of habitat structure were recorded and expressed as percentage of total area of transects investigated. Salinity was measured using salinity meter (LH-Y100) during every collection event.

During the field surveys, we also collected natural food organisms at habitats investigated and preserved them in 10% Formalin. In the laboratory, these prey items were separated, counted, measured and identified to the lowest possible taxon using a stereomicroscope (Meiji EMTR-3) and binocular microscope (Olympus CX22). Data of food analysis were expressed as percentage by number (%N) and percentage by volume (%V).

3. Results

3.1. Recruitment

Results of interviews (Table 1) showed that the recruitment of juveniles is different between the two study provinces. However, fish smaller than 3cm were caught mostly in the short period between July and August during 2005-2015 in both provinces. Larger juveniles, in contrast, were collected in different months (e.g. during May-June and October-November in Thua Thien Hue, and during February and September to December in Binh Dinh). The fishermen reported that about 1,700,000 juvenile fish (in Thua Thien Hue) and more than 58,000 fish (in Binh Dinh) were caught per year. Of these, about 85% were fish less than 3cm TL, which were collected mostly during July to August. This period is therefore considered as the major recruitment season of juveniles in central Vietnam.

3.2. Habitats of fish

Juveniles Mangrove Red Snapper were caught at sites in lagoons connected to rivers and mangrove forest where the salinity ranges from 10-25ppt (Figure 3). The information collected from fishermen (Table 1) showed that fish were mainly caught in rocky habitats, except the smallest size class (less than 3 cm), which usually was captured in sandy habitats in Thua Thien Hue and in seagrass habitats in Binh Dinh. Similarly, results from our field surveys (Figure 2) also showed that rocky areas were preferred habitat of all size classes of juvenile Mangrove Red Snapper.

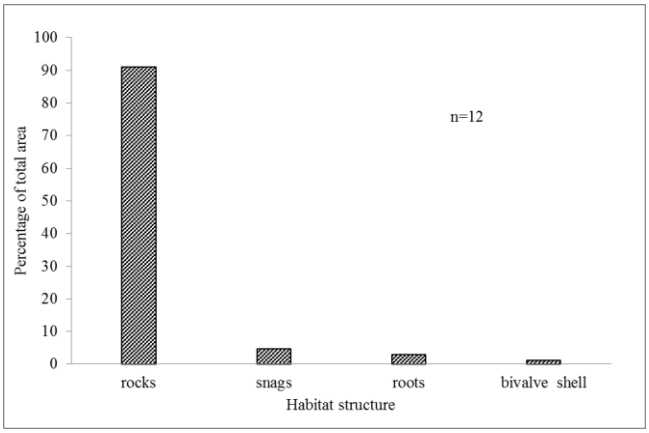

Fig 2: Natural habitat features in estuarine areas where juvenile Mangrove Red Snapper are most commonly caught by fishermen.

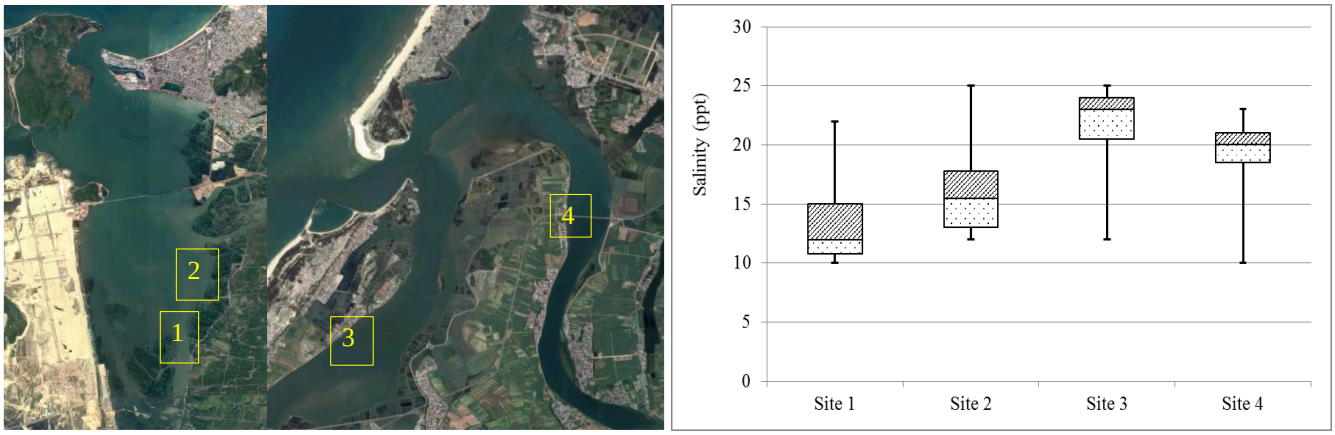

Fig 3: Salinity variation at study sites (site 1 and site 2 in Thi Nai lagoon, Binh Dinh; site 3 and site 4 in Tam Giang-Cau Hai lagoon, Thua Thien Hue).

Table 1: The recruitment and habitats of juvenile Mangrove Red Snapper.

Study sites	Fishing period (recruitment seasons)	Number of interviewed fishermen per total	Predominant size class	Main habitat	Total number of juveniles caught per year
Thua Thien Hue	May	3/48	3-10cm	Rock	1,691,800
	June	4/48	3-10cm	Rock	
	July - August	35/48	<3cm	Sand	
	October	3/48	5-7cm	Rock	
	November	3/48	5-10cm	Rock	
Binh Dinh	February	1/25	7-10cm	Rock	58,200
	July - August	20/25	<3cm	Seagrass	
	September - November	2/25	5-10cm	Rock	
	December	2/25	5-10cm	Rock	

3.3. Natural food

The results of the natural food analysis (Figure 4) showed the wide range of prey species associated with fish habitats, including shrimps, fish, crab, zooplankton and zoobenthos. Of which, shrimps were the dominant prey in both number and volume (e.g. *Acetes indicus* took 30.61% by number and 40.57% by volume; another species of *Acetes* held 10.2% by number and 20.17% by volume; or Mysidae comprised 17.86% by number and 13.6% by volume). Several zooplankton species (e.g. Calanoida or *Melita longidactyla*) were also abundant in number. These might be an important food resource of juvenile Mangrove Red Snapper in the wild

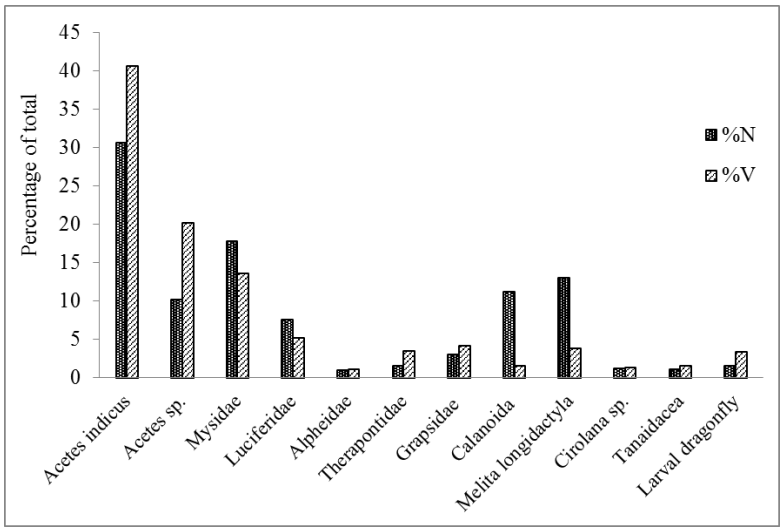

Fig 4: Natural food collected from lagoon environment where juvenile fish were mostly caught (expressed as percentage by number and volume).

3.4. Juvenile fishing

We found that the range of fishing gears used by fishermen was quite diverse, and varied between locations (Table 2). Stow nets and fish corrals were considered as the main fishing gears in Thua Thien Hue, which caught 51.66% and 33.31% of total fish per year, respectively, while seine nets were the preferred gear in Binh Dinh; this gear captured 85.91% of total fish per year. Most of the smallest juveniles (less than 3cm) were caught by these gears, whereas larger fish were captured by other techniques.

Table 2: Diversity of gears and practice of juvenile fishing by local fishermen at study locations.

Study sites	Fishing gears	Catching time	Proportion of fish caught per total (%)	Predominant size class of fish caught
Thua Thien Hue	Stow net	Night	51.66	<3cm
	Fish corral	Day and night	33.31	<3cm
	Scoop net	Day	0,65	3-10cm
	Lift net	Day and night	3,28	3-10cm
	Long trap cage	Night	11.10	5-10cm
Binh Dinh	Seine net	Day	85.91	<3cm
	Scoop net	Night	5,50	5-10cm
	Lift net	Day and night	3,44	3-10cm
	Long trap cage	Night	5,15	3-10cm

The time of deployment of fishing gear differed according to the type of gear used. Some fishing gears such as stow nets, long trap cages were operated at night, while seine nets were generally deployed during daytime. Passive gears such as fish corrals, lift nets were fished both day and night.

Most of fishers focused on catching juveniles <3cm, because they were considered as the main supply for aquaculture both within province and for export to other provinces. The larger juveniles comprised only a small proportion of the total number of juveniles captured per year, and these tended to supply only small local culture operations.

4. Discussion

Data collected from fishermen showed that in both locations the main recruitment of juvenile Mangrove Red Snapper often occurs in July to August, with a large number of <3cm fish caught. Whereas, there is a small number of fish captured in other seasons, and most of them are >3cm fish. However, it is noteworthy that aquaculturists also comment that the recruitment season of fish can vary between different years due to weather variation resulted from climate change. This is supported by our field surveys; that in 2015, principal settlement of fish changed to only occur in period of September-November, especially peak in September-October with a large number of small juveniles captured. In general, there might be only one major period of recruitment in year in central Vietnam despite its change due to annual different weather. Therefore, further studies are recommended to investigate how the weather affects the recruitment of this fish species.

It can be seen that although juvenile Mangrove Red Snapper can be caught in several periods of year, most fish are often captured in July and August. However, in eastern Thailand, large numbers of small juveniles (2-3cm TL) recruit into estuaries after wet season, during late October to January [8, 9], while in northern Australia, less than 5cm fish appear to recruit into freshwater riverine habitats in autumn and winter, between February and July [10]. It is clear that the recruitment of juvenile Mangrove Red Snapper occurs differently among geographical regions. It is believed that the different climate may be an important factor contributing to this difference.

During the field surveys, we found that juvenile Mangrove Red Snapper were mostly collected from waters with salinity range from 10ppt to 25ppt. Interestingly, although Australian researchers found juvenile Mangrove Red Snapper far upstream in rivers [10], there is no information indicating the presence of fish in freshwater in central Vietnam. This may reflect differences in the river systems and the way they are utilized by juveniles between the countries, or the result of intensive juvenile fishing in Vietnam removing surplus juveniles, which does not occur in Australia.

We found that larger juveniles (>3 cm total length) were mostly caught at rocky habitats. Similar results were also observed by Day *et al*. (1981) [11] and Russell *et al*. (2003) [11]. In contrast, <3cm fish were collected at seagrass bed in Binh Dinh and sandy bed in Thua Thien Hue. However, during the field surveys, we observed that in Binh Dinh, small juveniles only appeared at seagrass habitats several days before they were captured or moved to other habitats. Similarly, in Thua Thien Hue, most small fish were caught as soon as they recruited into the lagoon from the sea. Moreover, fish smaller than 3cm were also found at rocky habitats in both provinces; therefore, it is thought that seagrass and sand bed might not be preferred habitats of fish. In general, rocky areas could be the favourite habitats of juvenile Mangrove Red Snapper (≤10cm TL) in central Vietnam.

We also observed that fishing gears were diverse and different between locations. This might depend on traditional experiences of fishermen at each location. However, it is worth noting that use of these gears seem more or less to be related to movement of fish during the recruitment. The preferred fishing gears, such as stow nets and fish corrals in Thua Thien Hue or seine nets in Binh Dinh, are usually operated at sites in lagoons which are the nearest to the lagoon access to the sea, and result in a large number of fish <3cm caught. This indicates that most of the small juveniles are captured as soon as they recruit into coastal lagoons from offshore waters. Moreover, the chief harvesting period is the main recruitment season of juveniles (often in July-August: Table 1). However, when fish move to estuary or mangrove associated-rocky habitats, the preferred mass-harvest fishing gears as stow nets or seine nets appear not to be as effective; fishers then switch to use other gears such as scoops or long trap cages to collect fish. As a result, subsequent to the initial recruitment event, fishermen catch only small numbers of juveniles (mostly the bigger juveniles). Capture of juveniles becomes more haphazard and fishermen capture fish in different months (e.g. May, June, September, October, November).

Natural food is also an important aspect addressed in studying habitat ecology of fish. In the present study, we found a wide range of prey associated with habitats of juveniles Mangrove Red Snapper, of which shrimp prey were the most dominant. It is believed that habitat selection of this fish species may be related to these prey. Therefore, next studies are necessary to examine this aspect.

This study collected basic information related to the recruitment and habitat of juvenile Mangrove Red Snapper that might be useful for fish resource conservation. However, there are some ecological questions generated that should be considered by next studies, such as why fish select rocky habitats to reside or whether habitat selection is related to salinity, shelters and natural food availability.

5. Conclusion

The recruitment and habitat specificity of Mangrove Red Snapper have been examined. There is only one major recruitment season of juvenile in central Vietnam that often occurs in July - August. Juvenile fish prefer to inhabit in rocky habitats in brackish water areas where diversity of natural prey is found, with the dominance of shrimp prey. The information collected in this study would be useful and basic to conduct next studies that tend to conserve fish resource.

6. Acknowledgement

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